KNIK ARM CROSSING

TECHNICAL MEMORANDUM No. 15

Marine Biological Studies

December 20, 1983

U.S. Department of Transportation
Federal Highway Administration

Alaska Department of Transportation
and Public Facilities

A Report Prepared By

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for

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KNIK ARM CROSSIN G

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KNIK ARM CROSSING
MARINE BIOLOGICAL STUDIES

A. INTRODUCTION

This study was initiated as part of a baseline data collection program relating to environmental analysis of the proposed Knik Arm Crossing Project. The crossing alternatives (bridge, causeway, tunnel, etc.) have the potential to alter the physical characteristics of Knik Arm to varying degrees and, consequently, affect the marine biota. The importance of Knik Arm to fish and other members of the marine biological community was perceived as a significant information gap. This initial study was intended to provide insight into the ecology of Knik Arm with special emphasis on the behavior and ecology of juvenile salmon as they pass through Knik Arm during their annual migration from natal streams to saltwater rearing areas.

Knik Arm is a glacial estuary that likely constitutes one of the most extreme physical habitats in the world. Maximum tidal range of 12 m (39 ft) is second only to the Bay of Fundy in eastern Canada. Tidal currents in excess of 3.4 m/sec (11 ft/sec) are documented (Britch 1976). The currents and resulting turbulence produce high levels of suspended sediment (values to 1,350 mg/l are reported [Kinney et al. 1968]). Major glacial rivers continue to contribute massive quantities of sediment as does erosion of the near continuous expanse of coastal bluffs. Seabed conditions are likewise inhospitable including dynamic gravel beaches, armored cobble and boulder beaches and troughs, highly mobile fine silty sands, very soft but relatively stable silty mud, and fairly firm and stable mud flats. On any one summer day, salinity can vary from 6 to 20 parts per thousand (ppt) depending on tide stage. The combination of extreme tides and turbidity, strong currents, and mobile bottom sediments has discouraged biological research and lead to the widespread conviction that, except for seasonal passage of anadromous fish (Pacific salmon and eulachon), occasionally pursued by beluga whales, Knik Arm is a very unproductive environment (Bakus et al. 1979).

Biological research within Knik Arm has been sparse and limited to the extreme outer portion. Bakus et al. (1979) investigated some portions of the biological community in the vicinity of Point Woronzoff and concluded that subtidal infauna were essentially nonexistent and that intertidal life was very poor. The diversity and abundance of plankton was also less than that observed at other locations.

As far as is known, this study is the first to look in detail at fish in Knik Arm. A reconnaissance study (Blackburn 1978) using trawling and beach seining techniques was conducted in Cook Inlet with samples collected as far north as the East Forelands, about 129 km (80 miles) southwest of the entrance to Knik Arm.

B. METHODS

A boat-based sampling program was conducted in Knik Arm during the 5-week period from May 10 to June 9, 1983.

Beach Seine

The primary gear used to capture young salmon and other fish was a beach seine constructed of knotless nylon netting and measuring 37 m (120 ft) in length, 2.44 m (8 ft) deep at the bag, and 0.9 m (3 ft) deep at the ends. The wings are 18 m (59 ft) in length and consist of 3/8-inch bar mesh. The bag measures 0.6 m (2 ft) wide by 2.44 m (8 ft) deep by 2.3 m (7.5 ft) long and has 1/8-inch bar mesh.

Beach seining methods were similar to those used by various investigators during studies of juvenile salmon within estuaries. One person stood on the beach holding one end of a 33-m (100-ft) tow rope while the boat containing the net backed out perpendicular to the beach. At the end of the rope, the boat was turned 90 degrees and the seine was placed in the water as the boat backed up parallel to the beach in the same direction as the current. After deploying the net, the boat returned to the beach while playing out the second 33-m tow rope. The beach seine was then pulled by hand through the water onto the beach. The area sampled by the beach seine was approximately 900 m^2 (1076 yd^2). However, in practice, widely varying current conditions required some flexibility in net deployment and often the area sampled was less than the ideal. At least two sets were made at each station on each sampling trip except in cases where tide conditions prevented replicates. Beach seining was attempted at all tide stages but some stations could not be successfully seined at extreme low or extreme high tide.

Four fixed sampling stations were established on each shoreline of Knik Arm and an additional station was established on Middle Shoal (Figure 1). The stations were selected during an initial reconnaissance on the basis of the following characteristics:

1. Accessibility and seinability during a wide range of tide conditions.

2. Beach slope sufficiently steep to allow the net to fish at its full depth.

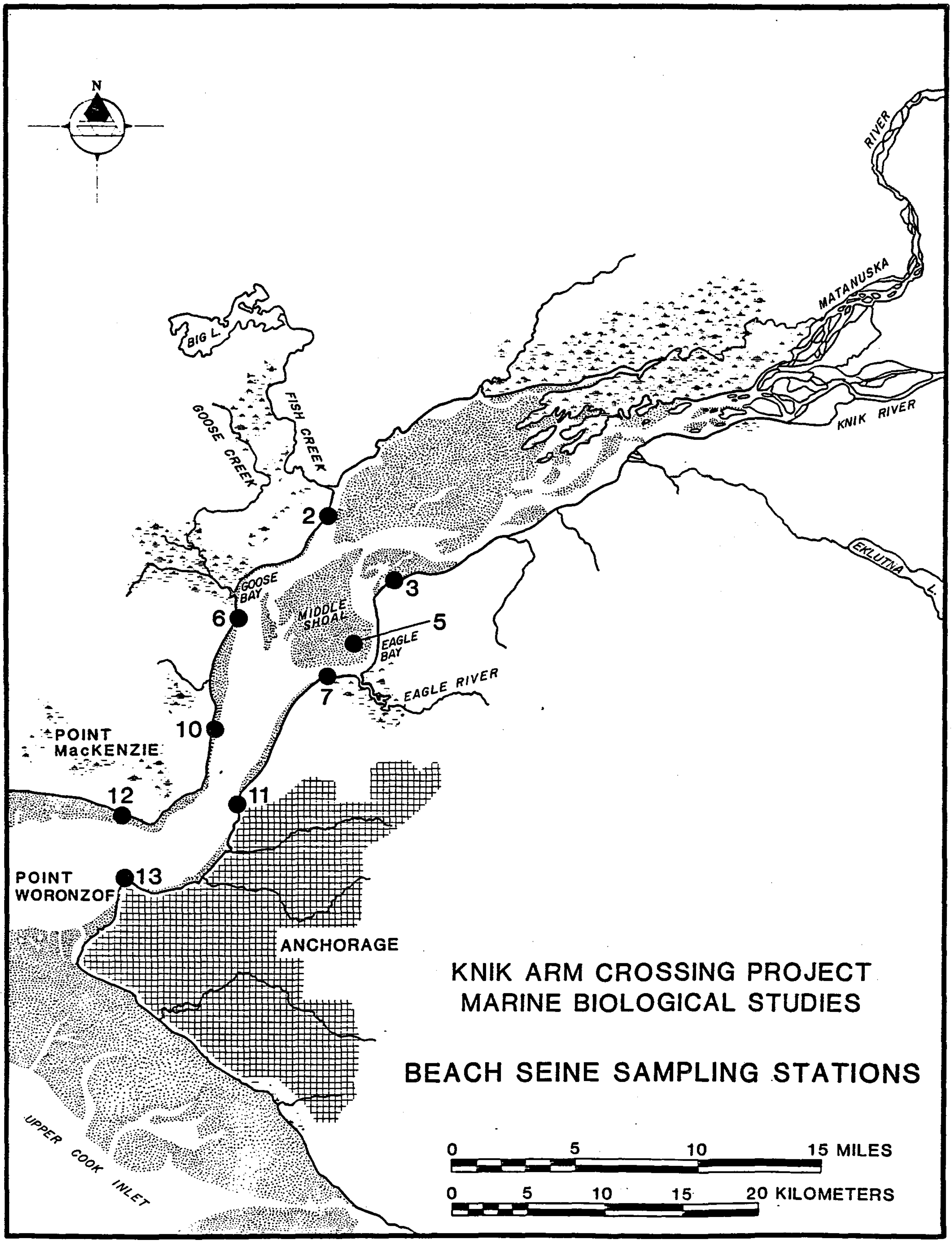
3. Safe footing (soft mud substrates were avoided when possible).

4. Location in relation to proposed crossing sites.

5. Location in relation to possible areas of ecological importance.

All of the shoreline sample stations had predominantly gravel substrate at mid to upper tide levels while substrate at the Middle Shoal station (Station 5) consisted of fine sand and silt.

The initial intent was to sample each fixed station at 5 or 6 day intervals. The actual sampling schedule varied somewhat from the planned schedule because of tide and weather conditions and equipment maintenance demands. Two days were normally required to sample all 9 stations.



DAMES & MOORE

Figure 1

Generally, all fish captured in the seine were measured and recorded. However, when large numbers of the same species were captured, a representative sample only was measured. All juvenile salmonids were preserved in 10 percent formalin and retained for confirmation of species identification and stomach content analysis. Representative samples of other species were also retained. Invertebrates captured in the seine were retained and preserved along with the fish samples.

Otter Trawl

A small otter trawl having a 3.1 m (10 ft) wide mouth, 3.8 cm (1.5 in) mesh body, and 0.6 cm (0.25 in) mesh bag was employed at several locations. Irregular bottom conditions prevented its continued use in most areas and only one station was sampled regularly (Eagle Bay trough, Figure 1). Standard tows of 2 to 5 minutes were made travelling at 1 to 2 knots faster than the water current. Tows were made in the direction of the current.

Epibenthic Sled

An epibenthic sled was adapted to qualitatively sample potential epibenthic fish food organisms. The epibenthic sled carried a 1-meter long, tapered nylon plankton net of 0.209-millimeter mesh, 30 centimeters (12 in) high by 50 centimeters (20 inches) wide at the mouth. A standard plastic net bucket with mesh covered ports was attached at the cod end. The net was mounted on a stainless steel frame that allows towing across irregular hard or soft bottom and was a modification of that used successfully by researchers collecting king crab postlarvae in lower Cook Inlet. Standard tows of 2 or 5 minutes were made at approximately 1 to 1.5 knots at selected stations. Organisms and detritus clinging to the net were washed into the net bucket. The entire contents were transferred to a wide-mouth jar, labeled, and preserved with buffered 10 percent formalin. The samples were later examined in the lab and invertebrate organisms were separated from the large quantities of detritus.

Core Samples

A 10-cm (4-in) deep cylindrical corer with a 43.7 cm^2 (6.8 in^2) opening was used to take triplicate cores of beach sediments in the lower intertidal range on selected transects. Sediments were seived on a 1.0 mm (0.4 in) screen and residue was examined under a dissecting scope for organisms.

Fish Stomach Content Analysis

Stomach contents were examined from most juvenile salmon and from representative samples of other species. Food organisms were identified and enumerated. Species identification of crustaceans was confirmed by Jeff Cordell, University of Washington.

C. RESULTS

Seine Catch Data - Fish

It should be emphasized that beach seining is at best a semi-quantitative technique and numerous variables such as current velocity, tide stage, depth, and presence of snags affected the efficiency of the netting operation. Therefore, catch per unit effort (catch per set) data should be interpreted with caution. Additionally, catch per set (CPS) for each period is not strictly comparable since stations were not consistently sampled at the same tide stage and, during some sampling periods, one or two stations were omitted entirely for various reasons. In spite of these cautions, we feel that the analyses presented below do provide an indication of general trends.

Total catch from the beach seine sampling program is presented in Table 1 and catch by station and sampling period is presented in Appendices A and B respectively. Eighteen species of fish were captured with an average catch of 48 fish per seine set.

TABLE 1

Total Fish Caught by Beach Seine in Knik Arm During the Period May 11 - June 8, 1983. The Data Resulted from 114 Sets or Hauls of the Seine.

Species	Total Catch	Catch per Set (CPS)
Chum Salmon (*Oncorhynchus keta*)	103	0.9
Sockeye Salmon (*O. nerka*)	53	0.5
Coho Salmon (*O. kisutch*)	78	0.7
Chinook Salmon (*O. tshawytscha*)	38	0.3
Pink Salmon (*O. gorbuscha*)	10	0.09
Dolly Varden (*Salvelinus malma*)	3	0.03
Rainbow Trout (*Salmo gairdneri*)	1	0.01
Bering Cisco (*Coregonus laurettae*)	83	0.7
Eulachon (*Thaleichthys pacificus*)	228	2.0
Longfin Smelt (*Spirinchus thaleichthys*)	3	0.03
Saffron Cod (*Eleginus gracilis*)	181	1.6
Pacific Herring (*Clupea harengus*)	5	0.04
Ringtail Snailfish (*Liparis rutteri*)	21	0.2
Starry Flounder (*Platichthys stellatus*)	2	0.02
Yellowfin Sole (*Limanda aspera*)	2	0.02
Threespine Stickleback (*Gasterosteus aculeatus*)	4631	40.6
Ninespine Stickleback (*Pungitius pungitius*)	11	0.09
Pacific Staghorn Sculpin (*Leptocottus armatus*)	2	0.03
Total Fish	5455	48.0

Chum Salmon. During the study period, 103 juvenile chum salmon were captured. The CPS increased throughout the study with the highest catch occurring on the last sampling date (Figure 2). The CPS was somewhat higher on the east side of Knik Arm than on the west (Figure 3), although moderate numbers of chum salmon were captured at all stations.

The length/frequency relationship (Figure 4) indicates a single strong size group in the 31 to 39 mm (1.2 to 1.5 in) range. There is some suggestion of a small group of larger fish in the 47 to 51 mm (1.9 to 2 in) range that may be separate from the major group.

Coho Salmon. Seventy-eight juvenile coho salmon were caught with the highest CPS occurring on the May 31 to June 2 sampling period (Figure 5). Very small catches occurred early in the study. The CPS was higher on the west side of Knik Arm (Figure 6) with the highest catches occurring at Station 2.

The length/frequency relationship (Figure 7) indicates that four size groups may be definable with approximate mean lengths as follows: 35 mm (1.4 in), 75 mm (3 in), 122 mm (4.8 in), 163 mm (6.4 in).

Sockeye Salmon. Fifty-one juvenile sockeye salmon and two adults were captured in the seine. The catch of juveniles was very low at the start of the study, increased to a peak on the May 31 to June 2 sampling period then decreased somewhat on the June 7 to 8 period (Figure 8). Catches were more consistent on the west side of Knik Arm; however, the highest CPS occurred at Station 7 on the eastern shore (Figure 9).

The relatively small sample size makes the length/frequency distribution hard to interpret (Figure 10). However, at least one major peak occurred in the 55 to 57 mm (2.1 to 2.2 in) length range. There are hints of a smaller group and one or two larger groups.

Chinook Salmon. Thirty-five juvenile chinook salmon were caught as well as two adults and one precocious male (jack). Highest catches of juveniles occurred toward the end of the study period (Figure 11). None were caught

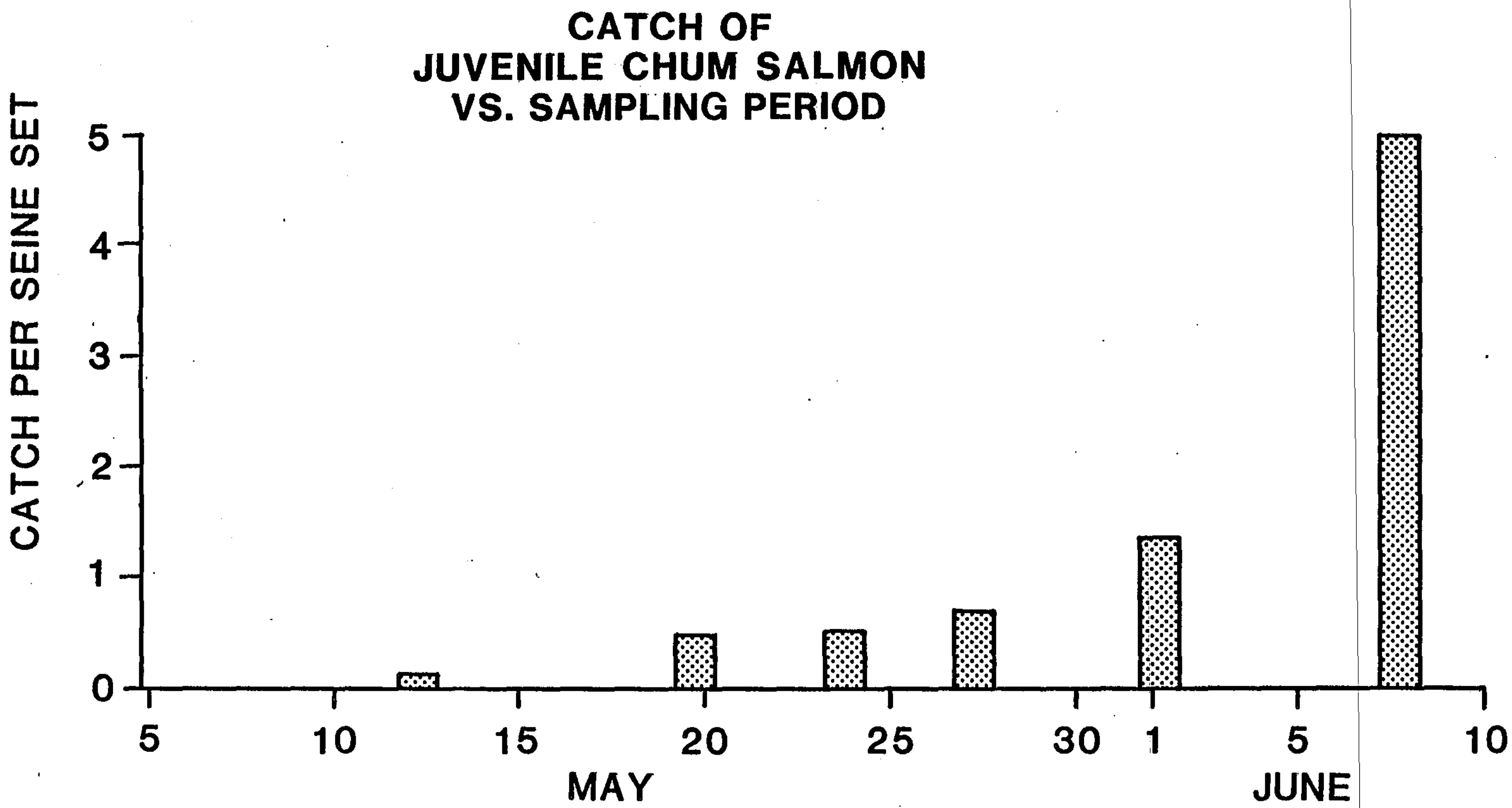
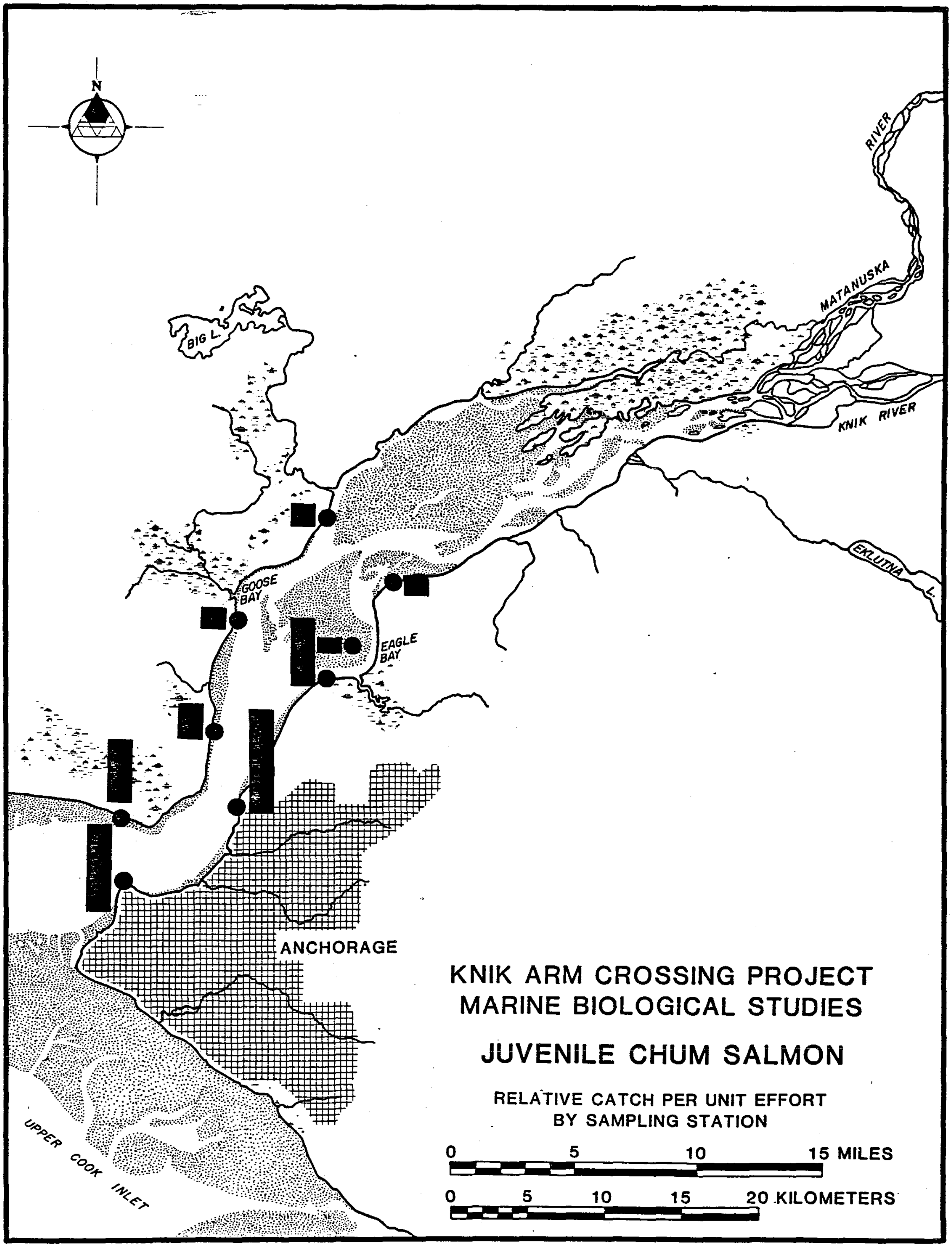

CATCH OF
JUVENILE CHUM SALMON
VS. SAMPLING PERIOD
CATCH PER SEINE SET
0
1
2
3
4
5
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 2



DAMES & MOORE

Figure 3

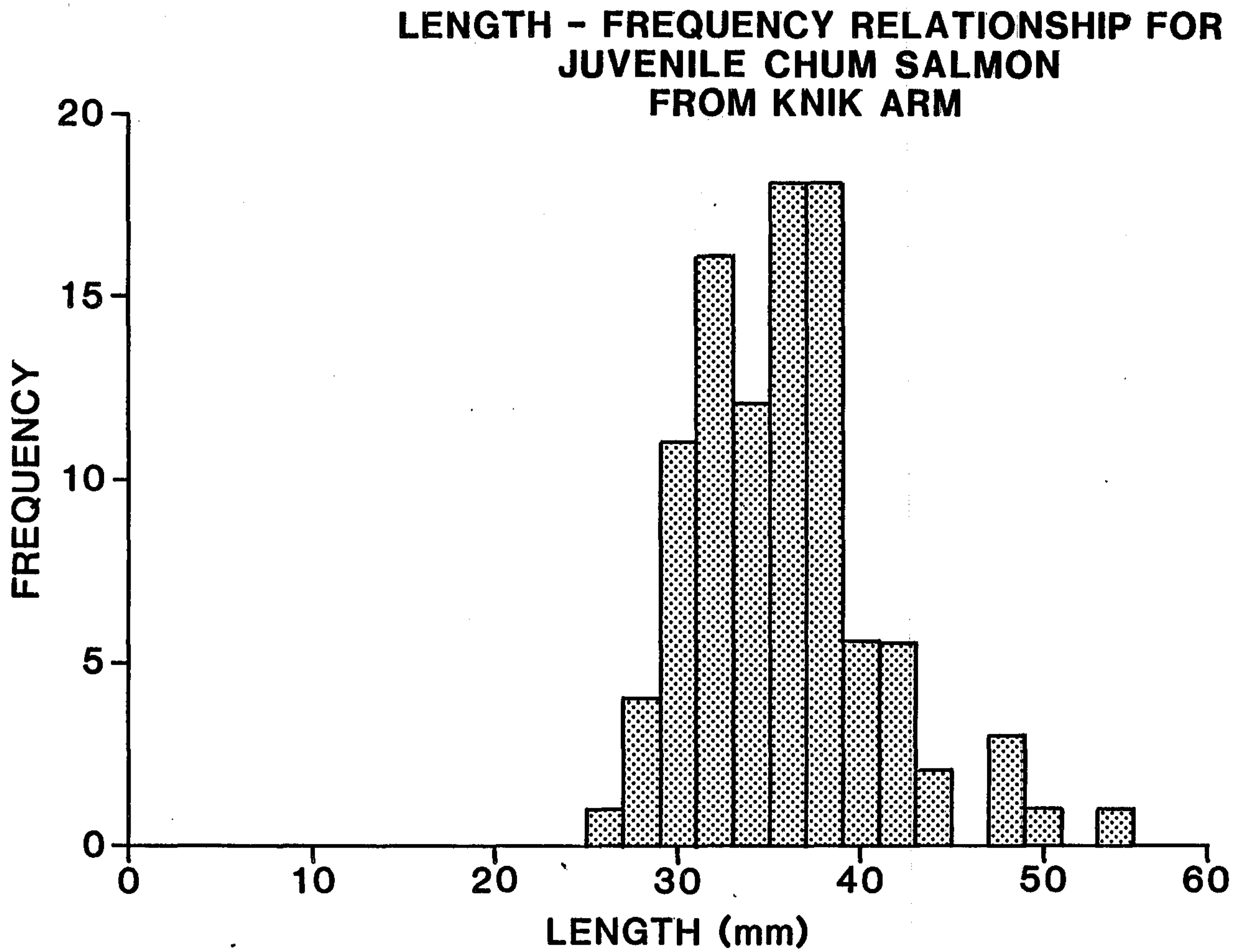

LENGTH - FREQUENCY RELATIONSHIP FOR
JUVENILE CHUM SALMON
FROM KNIK ARM
FREQUENCY
20
15
10
5
0
0
10
20
30
40
50
60
LENGTH (mm)

Figure 4

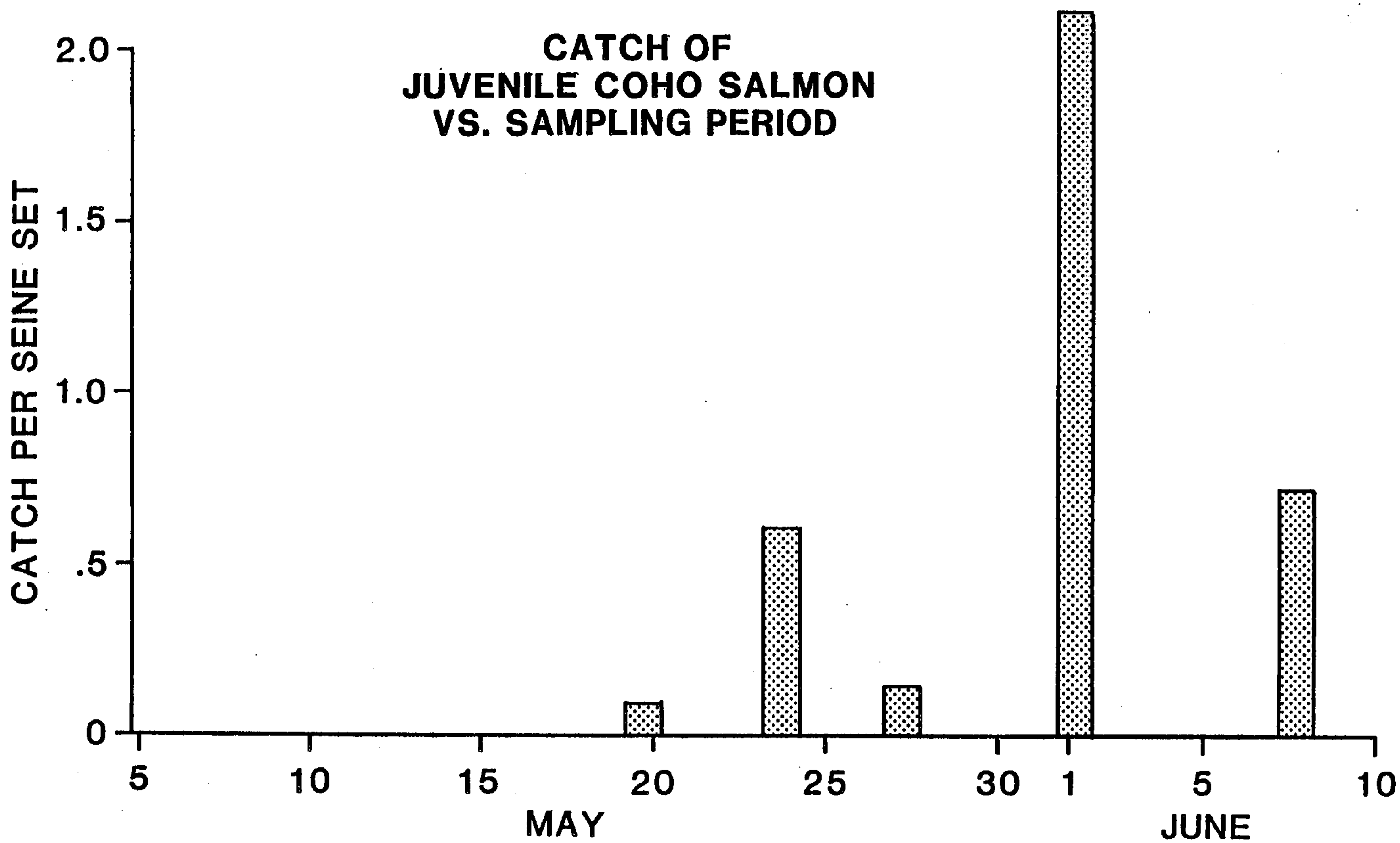

CATCH OF
JUVENILE COHO SALMON
VS. SAMPLING PERIOD
CATCH PER SEINE SET
2.0
1.5
1.0
.5
0
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 5

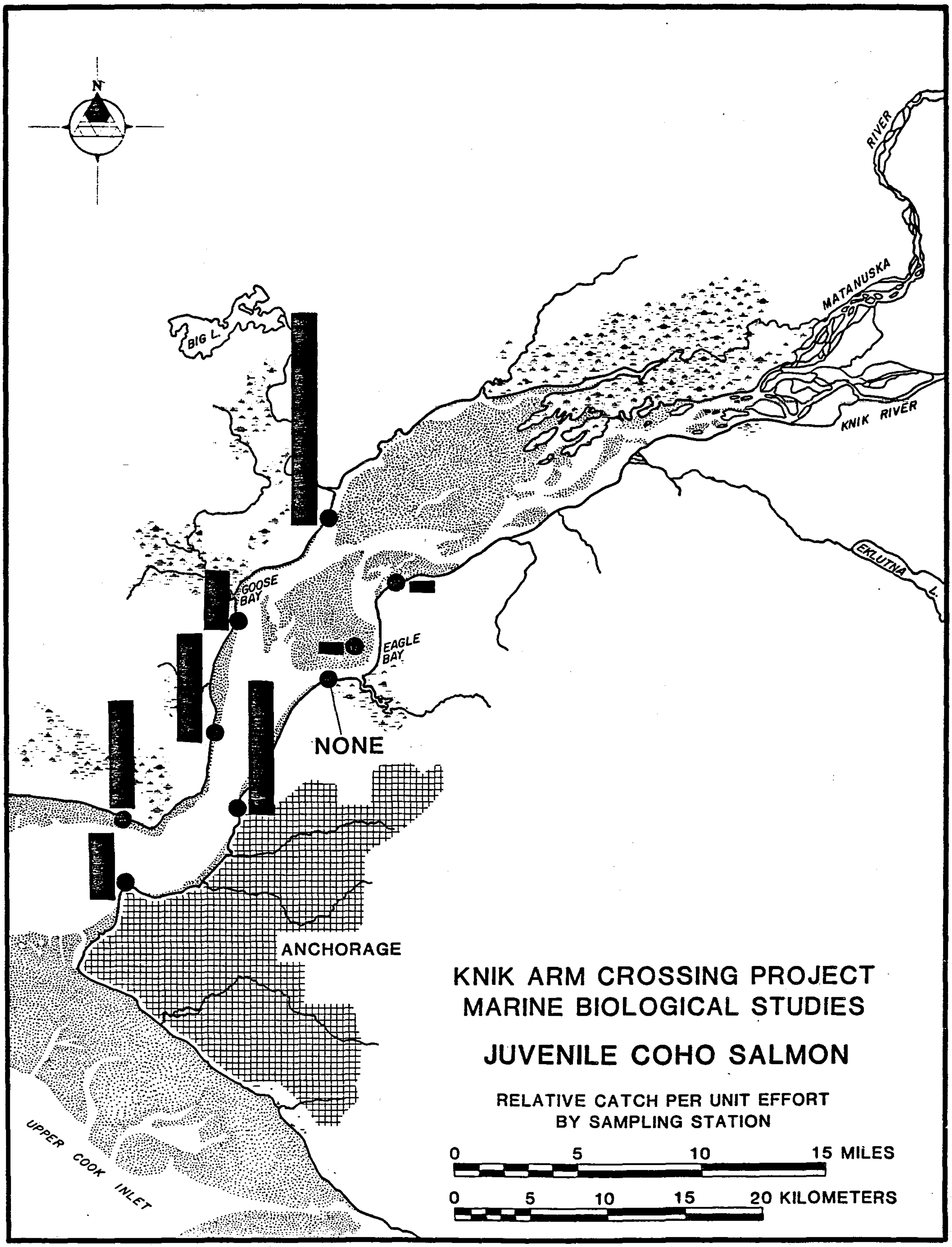


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Figure 6

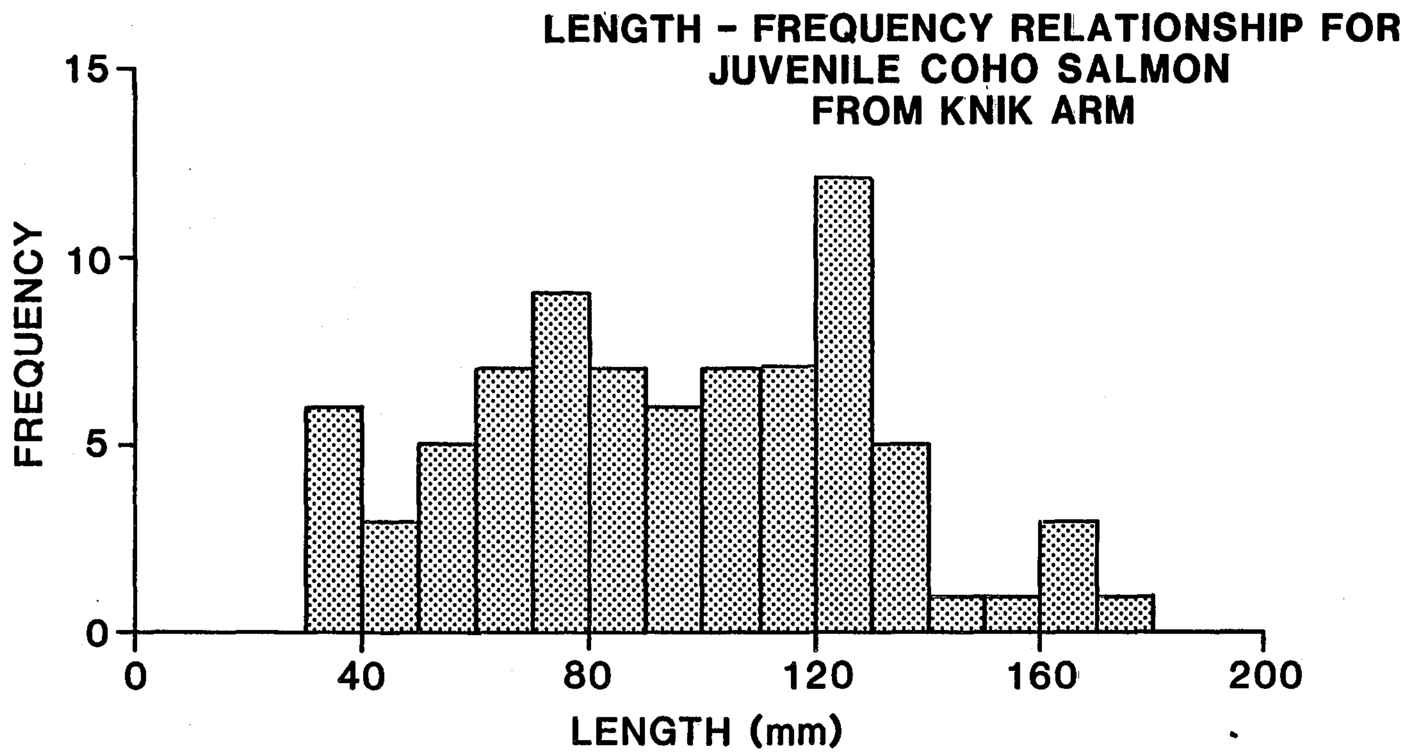

LENGTH - FREQUENCY RELATIONSHIP FOR
JUVENILE COHO SALMON
FROM KNIK ARM
FREQUENCY
0
5
10
15
0
40
80
120
160
200
LENGTH (mm)

Figure 7

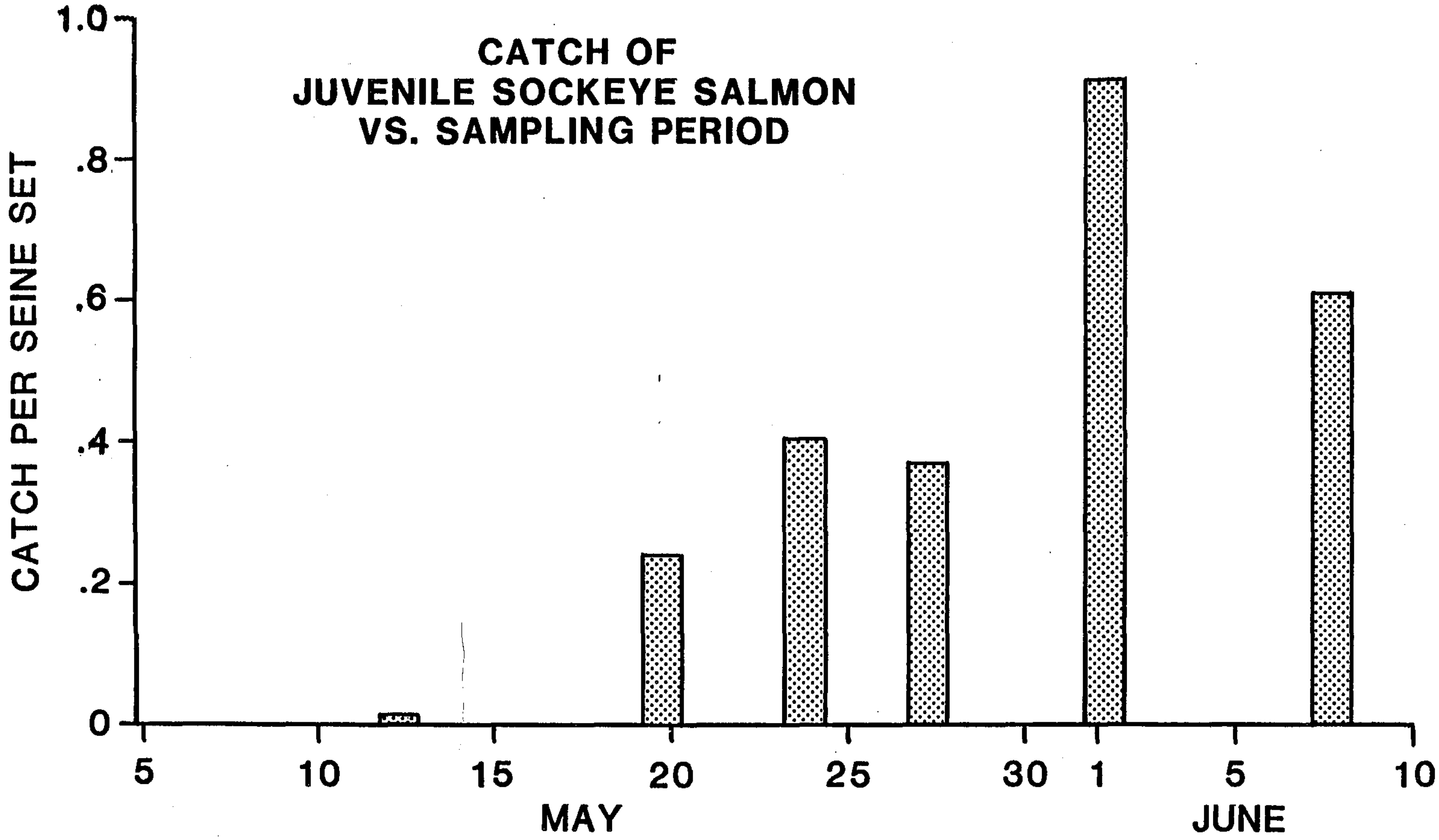
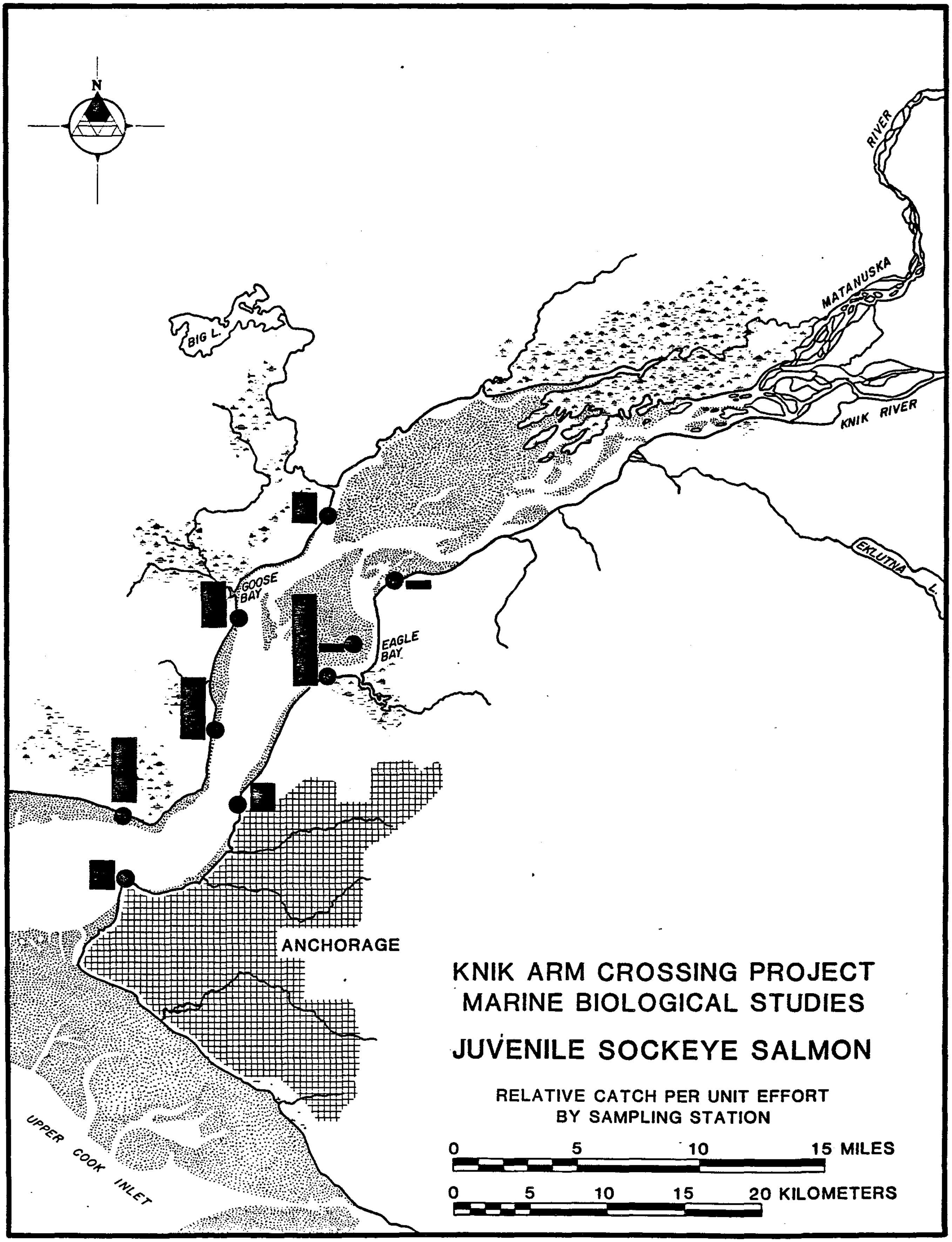

CATCH OF
JUVENILE SOCKEYE SALMON
VS. SAMPLING PERIOD
CATCH PER SEINE SET
1.0
.8
.6
.4
.2
0
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 8



KNIK ARM CROSSING PROJECT MARINE BIOLOGICAL STUDIES

JUVENILE SOCKEYE SALMON

RELATIVE CATCH PER UNIT EFFORT BY SAMPLING STATION

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Figure 9

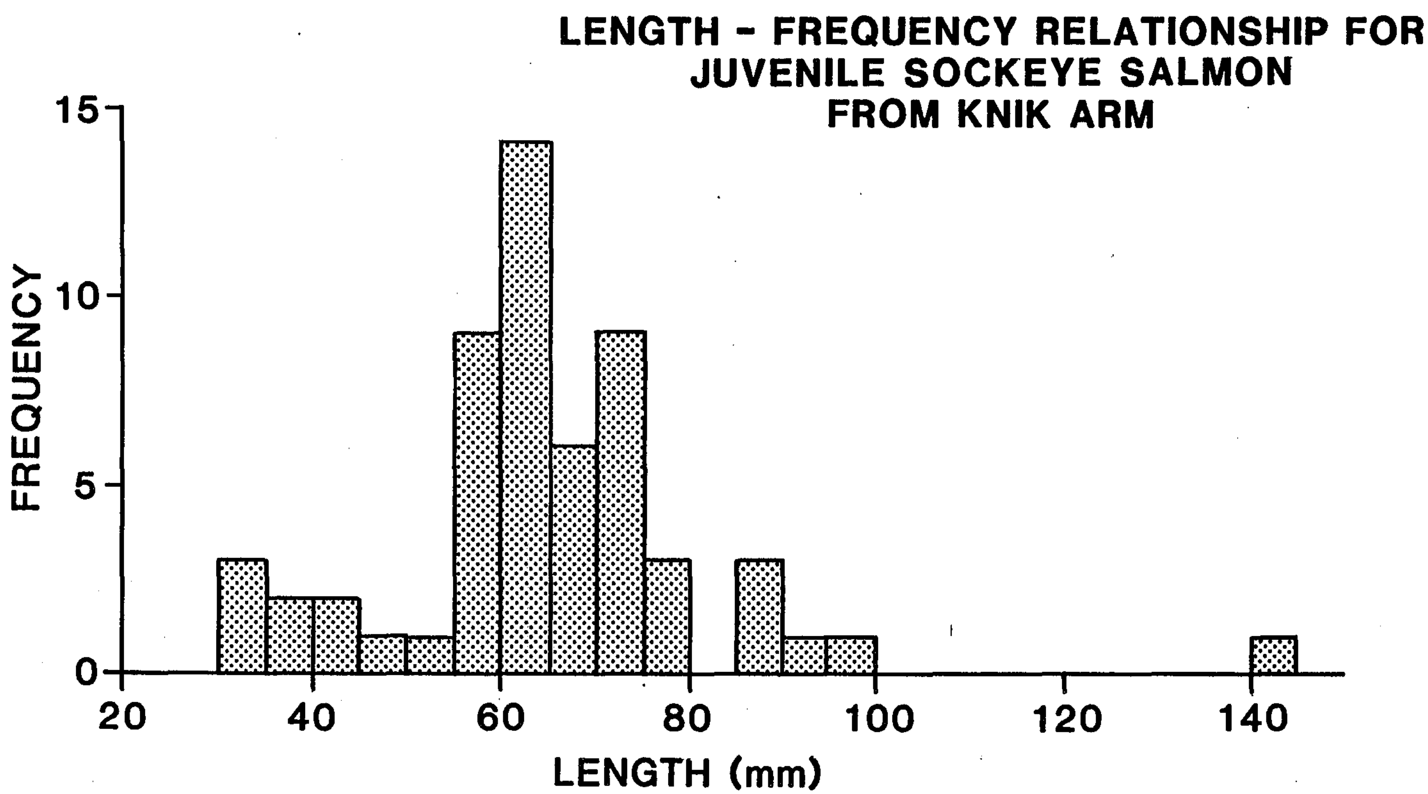
LENGTH - FREQUENCY RELATIONSHIP FOR
JUVENILE SOCKEYE SALMON
FROM KNIK ARM
FREQUENCY
15
10
5
0
20
40
60
80
100
120
140
LENGTH (mm)

Figure 10

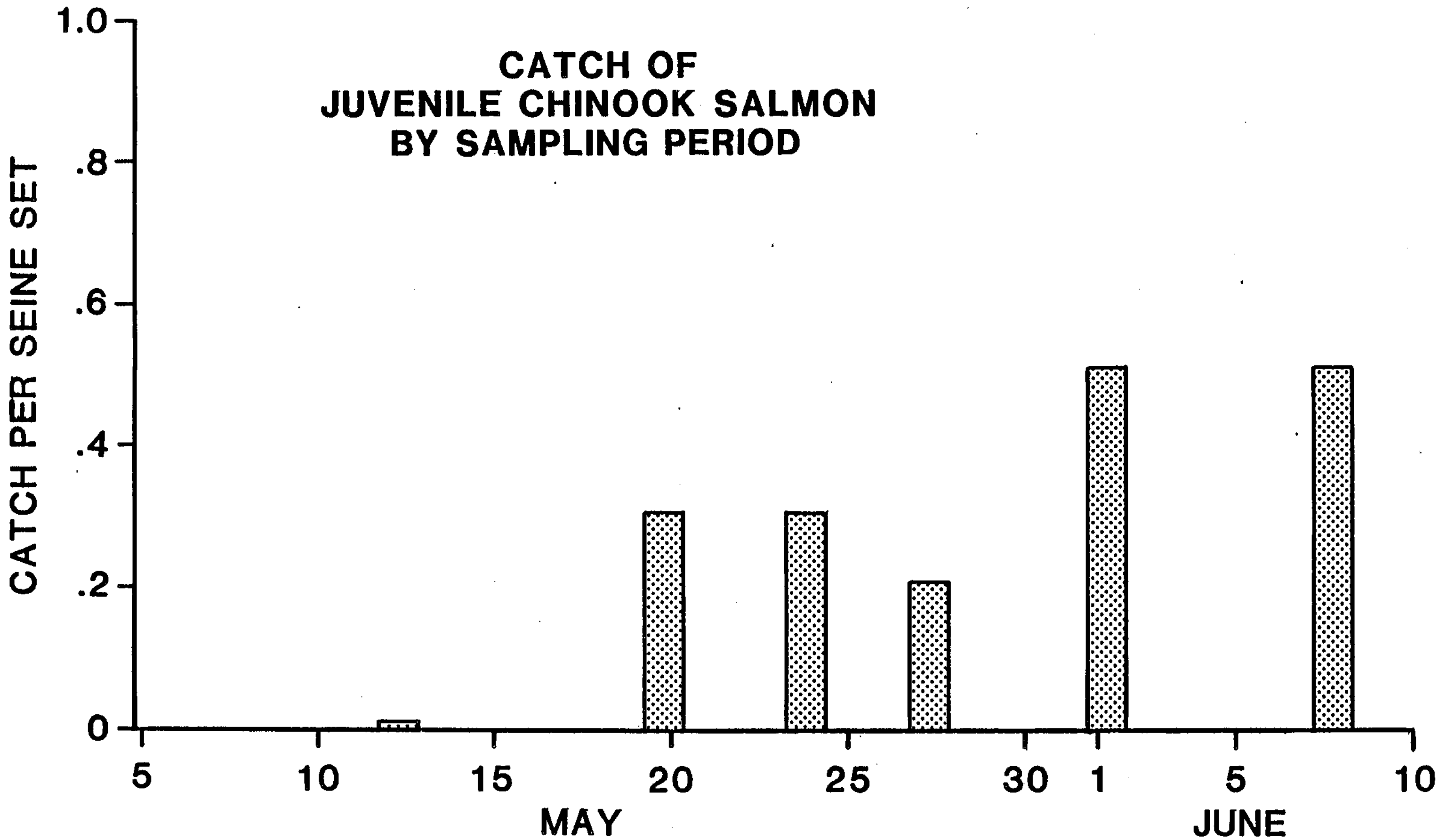
CATCH OF
JUVENILE CHINOOK SALMON
BY SAMPLING PERIOD
CATCH PER SEINE SET
1.0
.8
.6
.4
.2
0
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 11

during the first sampling period. Highest numbers of juvenile chinooks were caught at the outer sampling stations. Few were caught at Stations 2, 3 or 5.

Length/frequency analysis is hampered by small sample size but there appear to be three and possibly four size groups represented (Figure 12).

Pink Salmon. Only ten pink salmon fry were captured during the study, all during the period May 19 to May 27. Pink salmon were caught only at Stations 10 and 13.

Trout and Char. Three very small Dolly Varden juveniles (28 to 31 mm [1.1 to 1.2 in]) were caught in one seine set at Station 10 on June 2. One rainbow trout (a ripe male of 195 mm [7.7 in]) was caught on May 23 at Station 2.

Threespine Stickleback. Threespine stickleback were the most abundant fish sampled during the study with an average CPS of about 40 fish. These catch data are strongly skewed by several very large catches that occurred early in the study. Figure 13 indicates that by far the highest CPS occurred during the first sampling period then declined to a CPS of about 10 during the June 7 to 8 sampling period. Highest catches occurred on the west side of Knik Arm (Figure 14) with few threespine sticklebacks caught at Stations 11 and 13.

All threespine sticklebacks captured were adults in a very narrow size grouping (74 to 86 mm [3 to 3.4 in]).

Saffron Cod. Saffron cod was one of the more abundant and consistently captured fish species. The catch appeared to increase from the beginning of the study period to the end with the highest catch occurring on the last sampling period (Figure 15). The CPS was higher on the west side of Knik Arm and at the outer stations (Figure 16). Although cod were captured at all locations there appeared to be some preference for gravel bottom sites.

Most of the Saffron cod captured were juveniles representing two or possibly three age classes (Figure 17). A few adults in the 320 to 360 mm (12.6 to 14.2 in) length range were also caught.

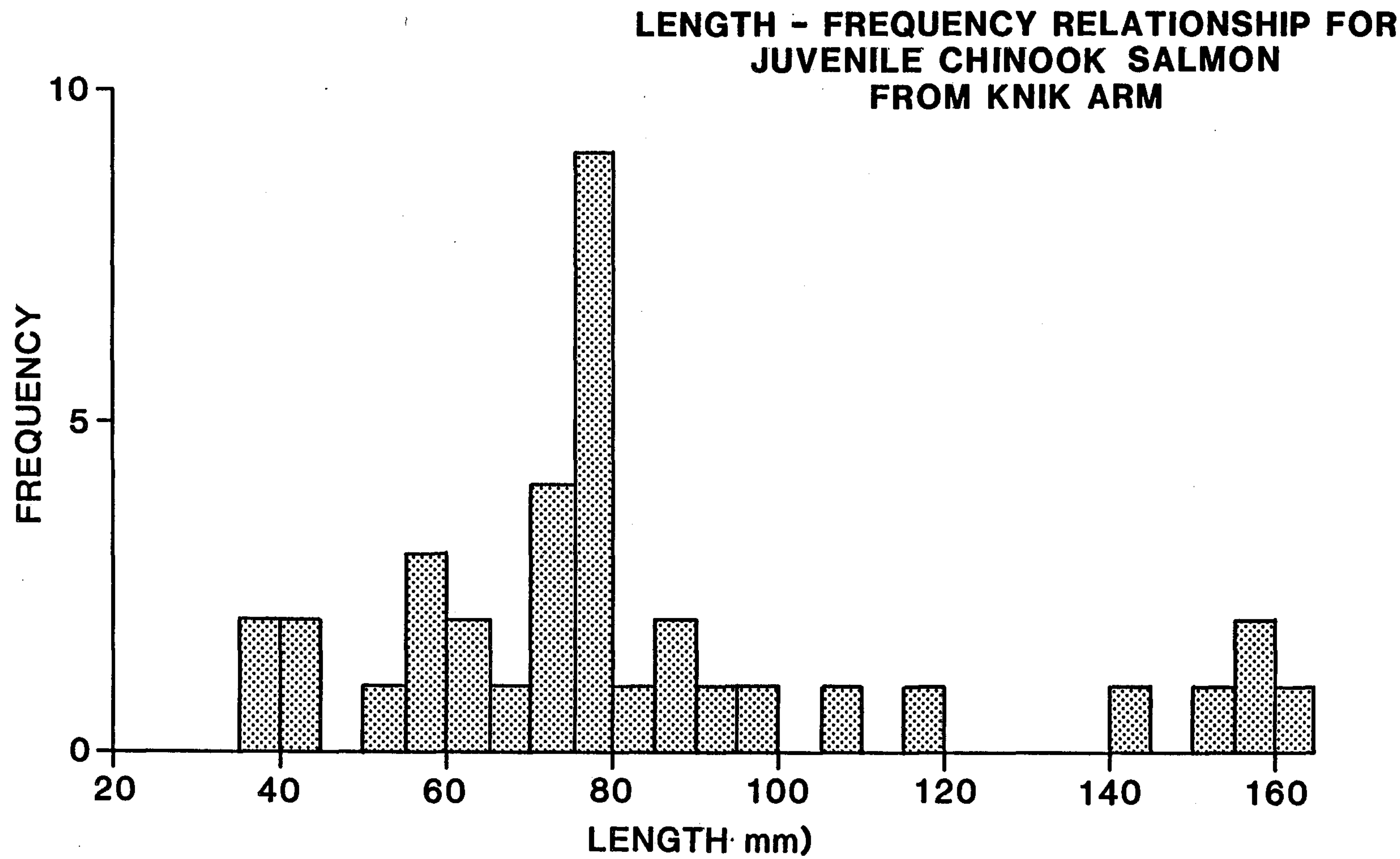
LENGTH - FREQUENCY RELATIONSHIP FOR
JUVENILE CHINOOK SALMON
FROM KNIK ARM
10
5
0
FREQUENCY
20
40
60
80
100
120
140
160
LENGTH· mm)

Figure 12

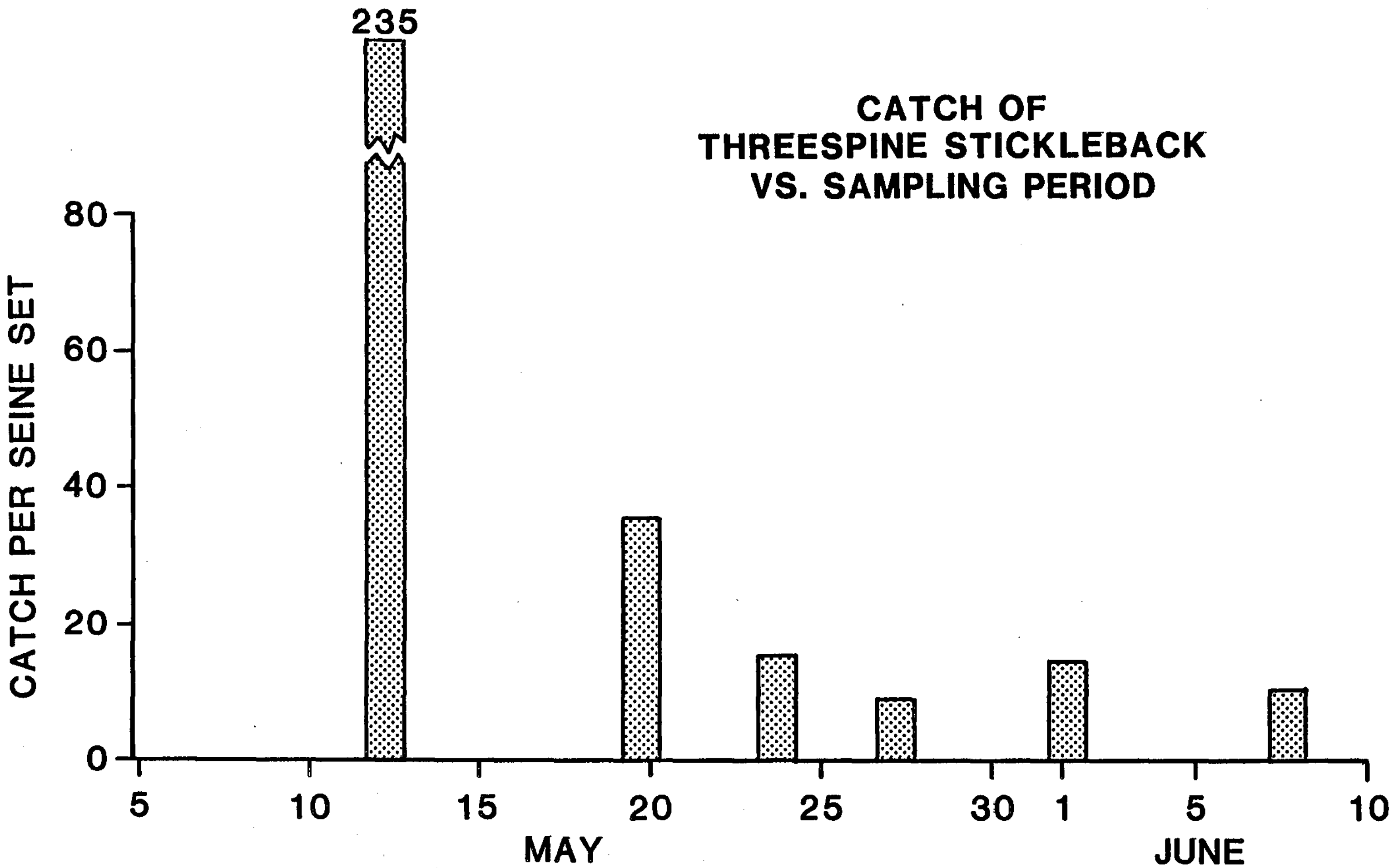
CATCH OF
THREESPINE STICKLEBACK
VS. SAMPLING PERIOD
235
CATCH PER SEINE SET
0
20
40
60
80
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 13

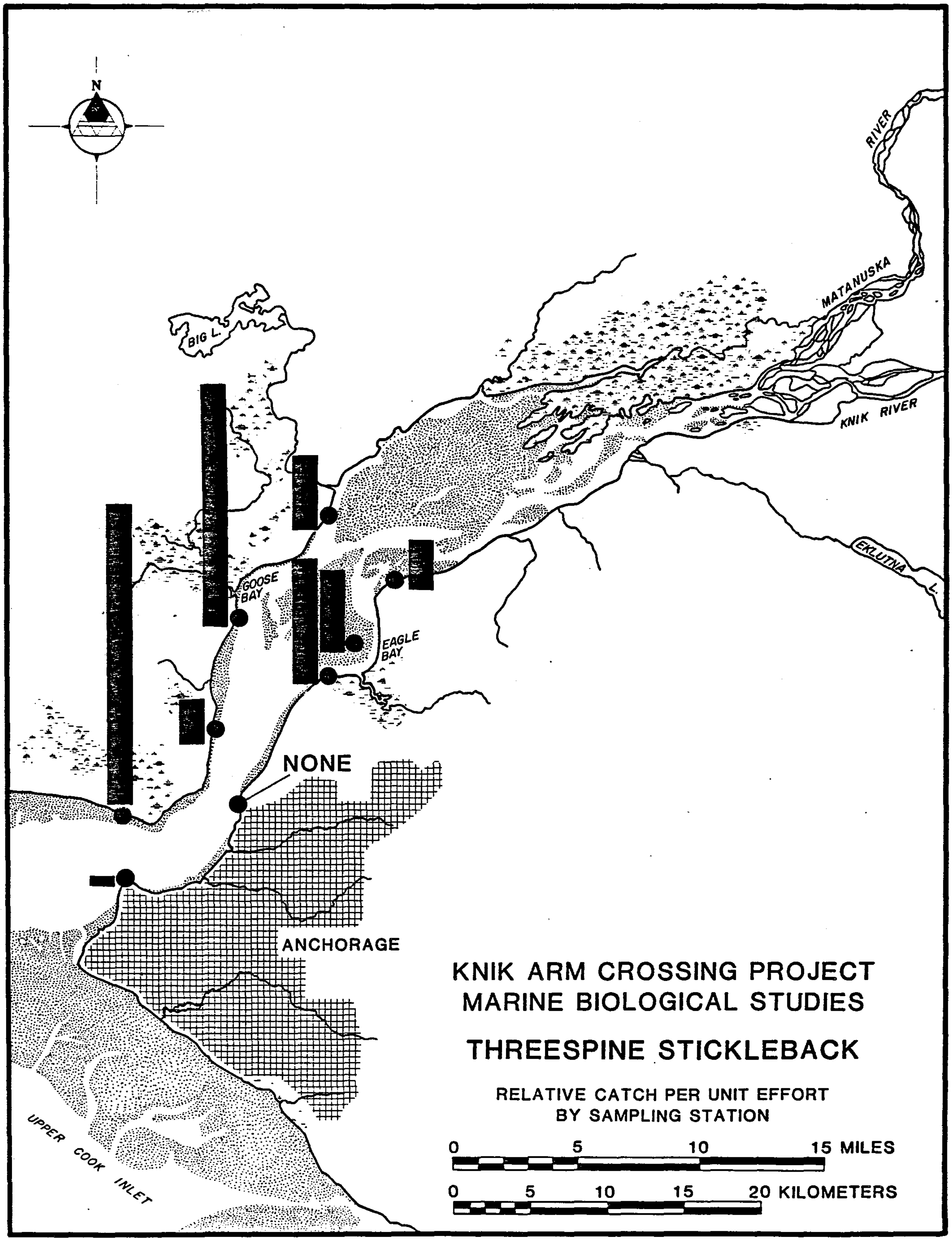

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Figure 14

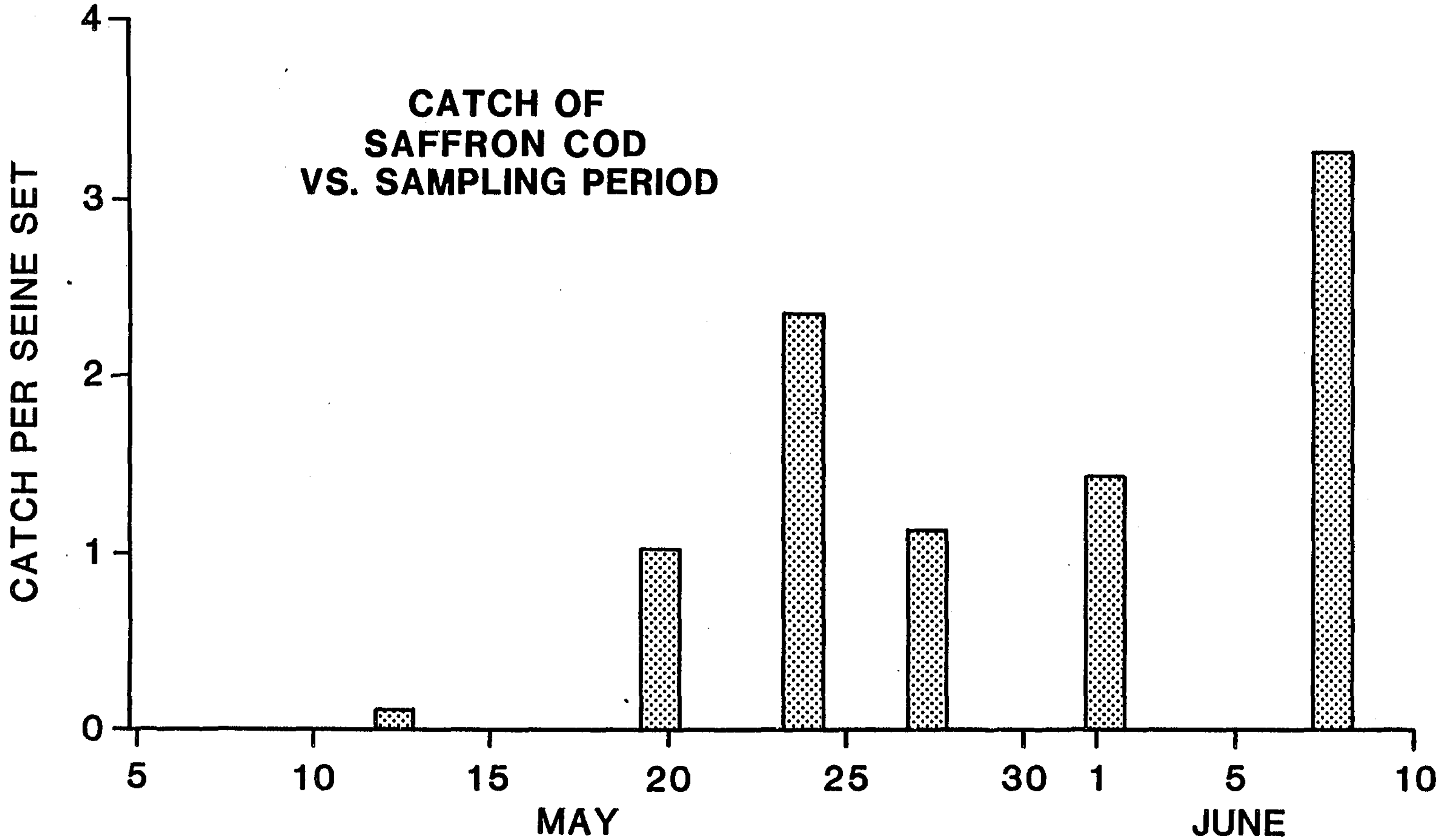
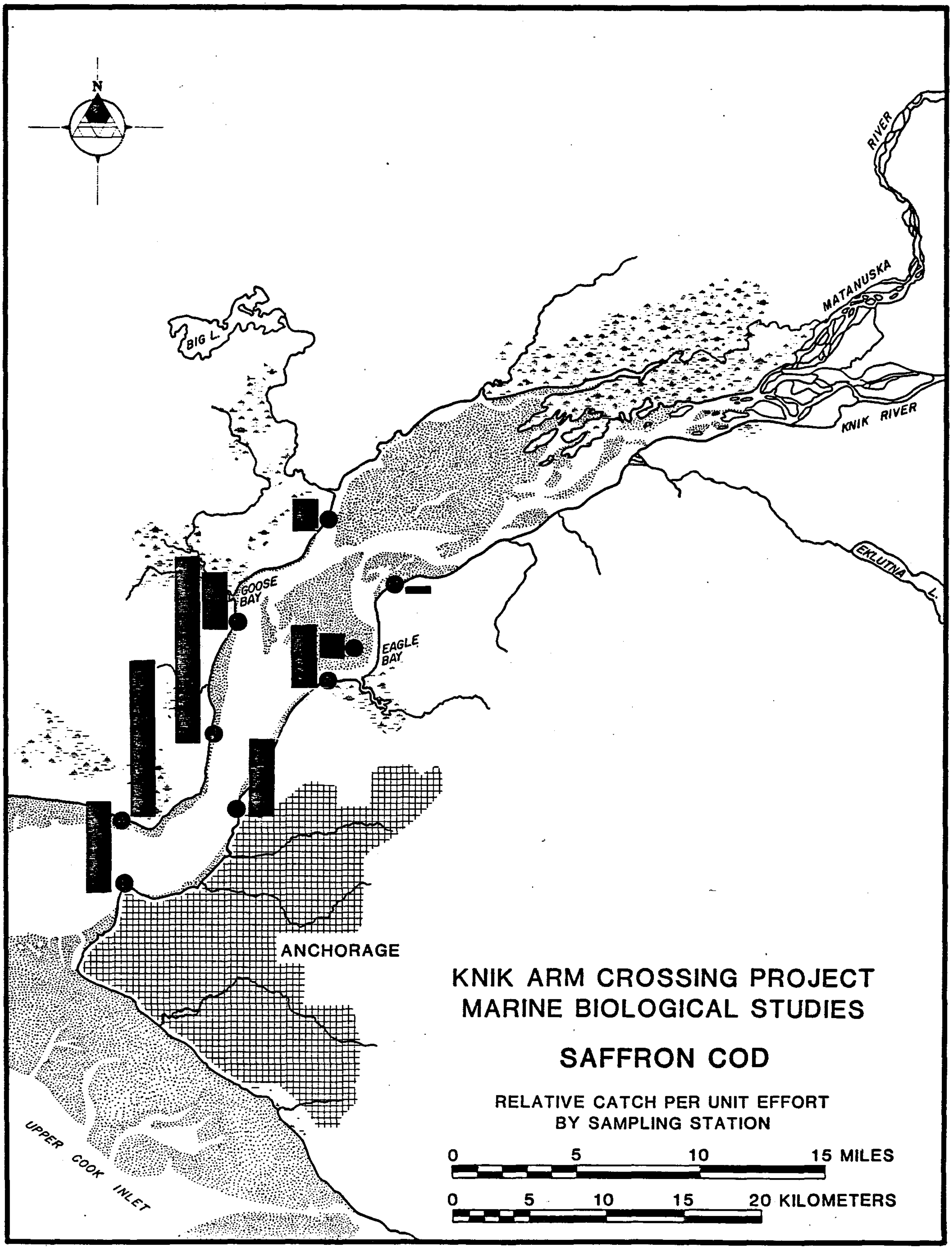

CATCH OF
SAFFRON COD
VS. SAMPLING PERIOD
CATCH PER SEINE SET
0
1
2
3
4
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 15



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MARINE BIOLOGICAL STUDIES

SAFFRON COD

RELATIVE CATCH PER UNIT EFFORT
BY SAMPLING STATION

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Figure 16

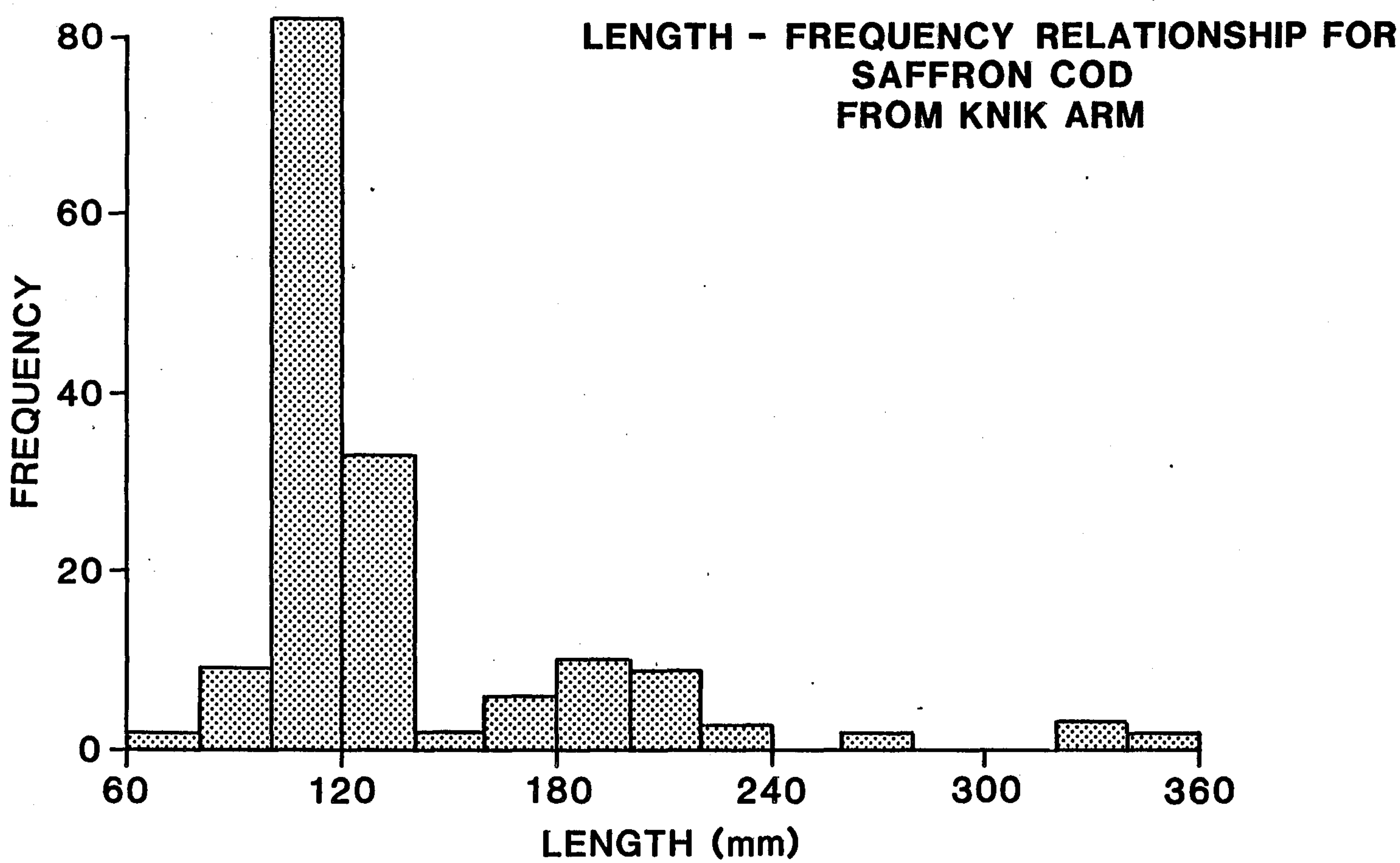
LENGTH - FREQUENCY RELATIONSHIP FOR
SAFFRON COD
FROM KNIK ARM
FREQUENCY
0
20
40
60
80
60
120
180
240
300
360
LENGTH (mm)

Figure 17

Bering Cisco. Bering cisco were caught consistently with an average CPS of 0.7. No obvious trends in abundance were noted during the study period (Figure 18). Fairly uniform numbers of cisco were caught at all stations except that none were caught at the two innermost stations (Stations 2 and 3) or at the mud shoal, Station 5 (Figure 19). Gravel habitats appeared to be preferred. Most age segments of the Bering cisco population appeared to be represented. Figure 20 suggests the presence of about four age groups including both juvenile and adults. No young-of-the-year ciscos were observed.

Eulachon. Eulachon (hooligan) were captured sporadically but, when caught, appeared in relatively large numbers. By far, the highest catch occurred during the May 31 to June 2 sampling period and Figure 21 suggests a population peak at that time. Eulachon were caught at all stations except Station 5 with somewhat higher numbers occurring on the east side of Knik Arm than on the west (Figure 22).

Most eulachon caught in the seine were adult fish in a narrow size group (190 to 220 mm [7.5 to 8.7 in]). A few smaller fish were also observed. Most eulachon were ripe or had spawned recently.

Snailfish. A total of 12 ringtail snailfish were caught in the beach seine during the study. These small fish were captured throughout the study period and were usually associated with gravel habitats and strong currents. All snailfish were apparently juveniles with lengths ranging from 40 to 87 mm (1.6 to 3.4 in).

Slow growing adults?

Other Species. As indicated in Table 1, several other species were caught in very small numbers including: longfin smelt, Pacific herring, starry flounder, yellowfin sole, ninespine stickleback, and Pacific staghorn sculpin. Most herring were juveniles and were associated with the outer sampling stations. However, two ripe adult herring (222 and 247 mm [8.7 and 9.7 in]) were taken at Pt. Woronzoff on May 20.

Tide Stage vs. Catch. The catch of major species has been compared according to tide stage at the time of capture in Table 2. There appears to be a trend

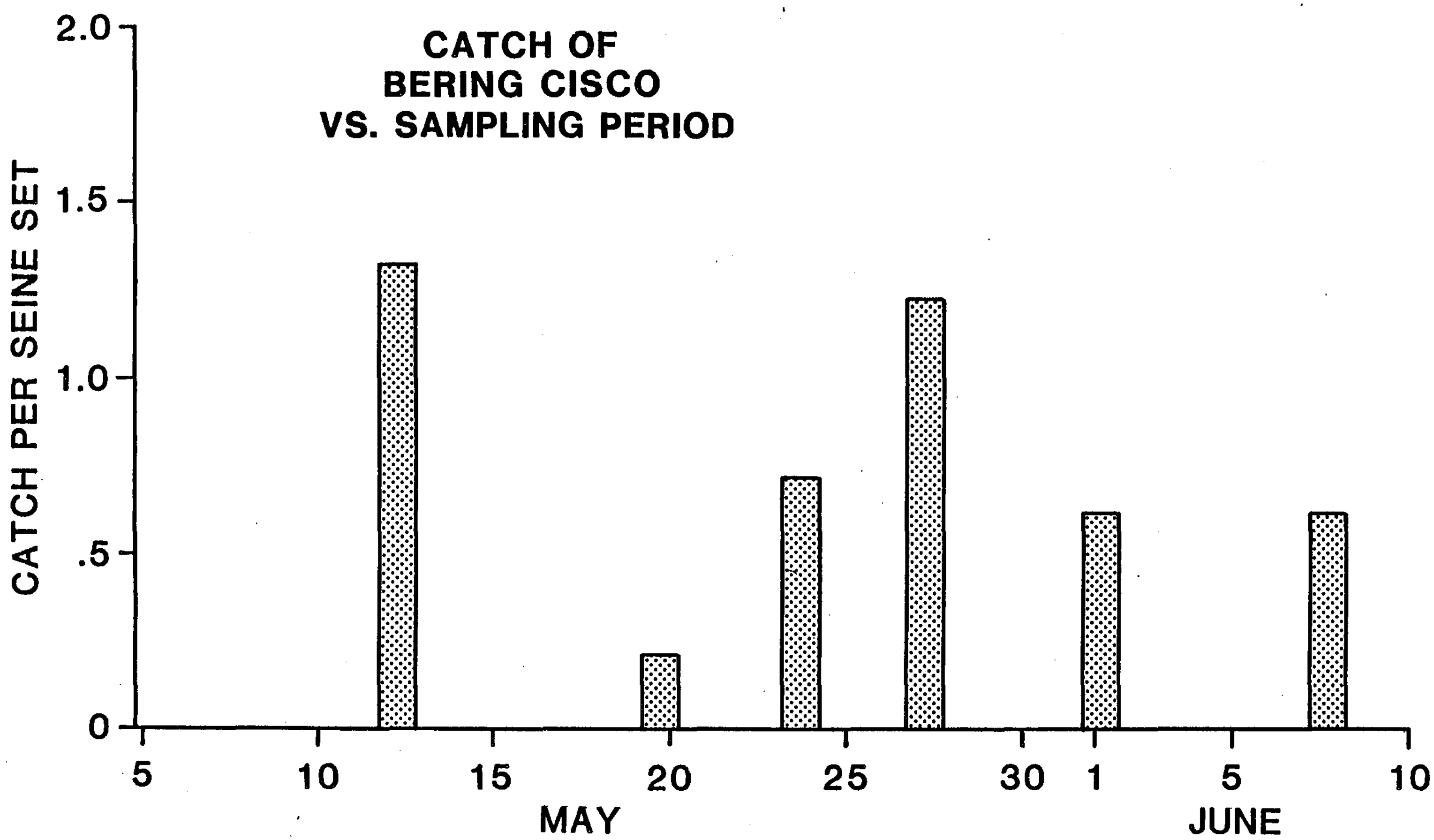
CATCH OF
BERING CISCO
VS. SAMPLING PERIOD
CATCH PER SEINE SET
2.0
1.5
1.0
.5
0
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 18

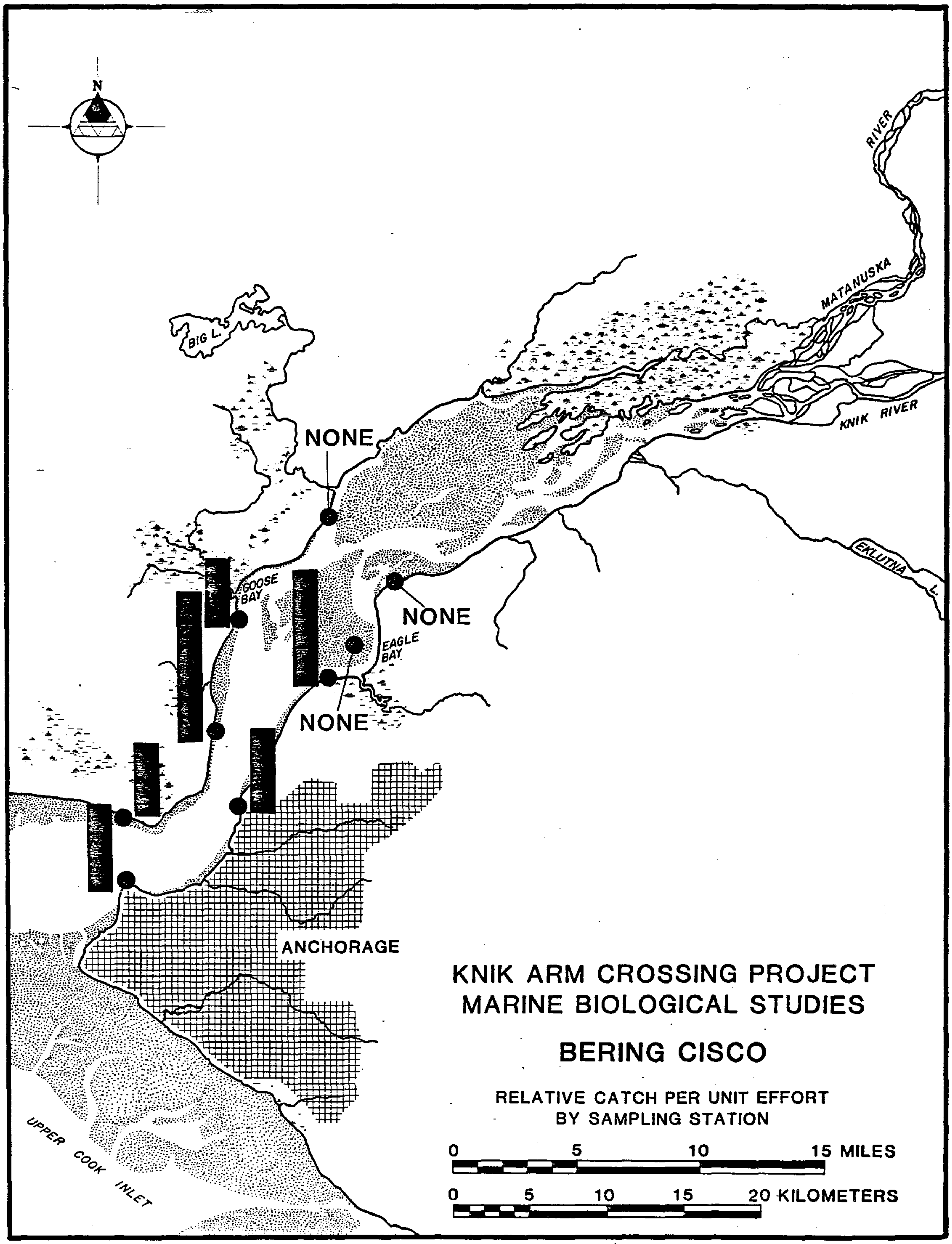

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Figure 19

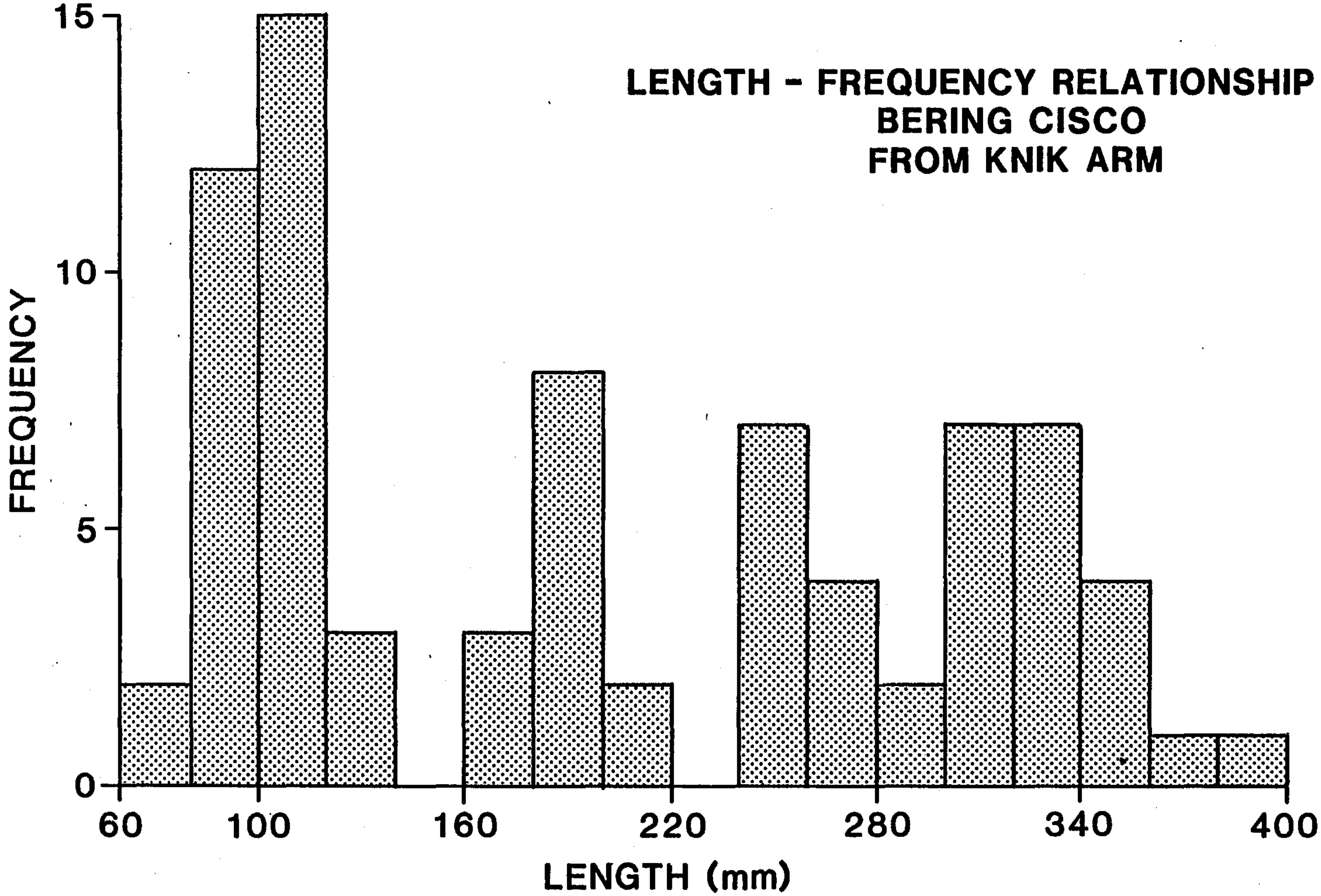

LENGTH - FREQUENCY RELATIONSHIP FOR
BERING CISCO
FROM KNIK ARM
FREQUENCY
15
10
5
0
60
100
160
220
280
340
400
LENGTH (mm)

Figure 20

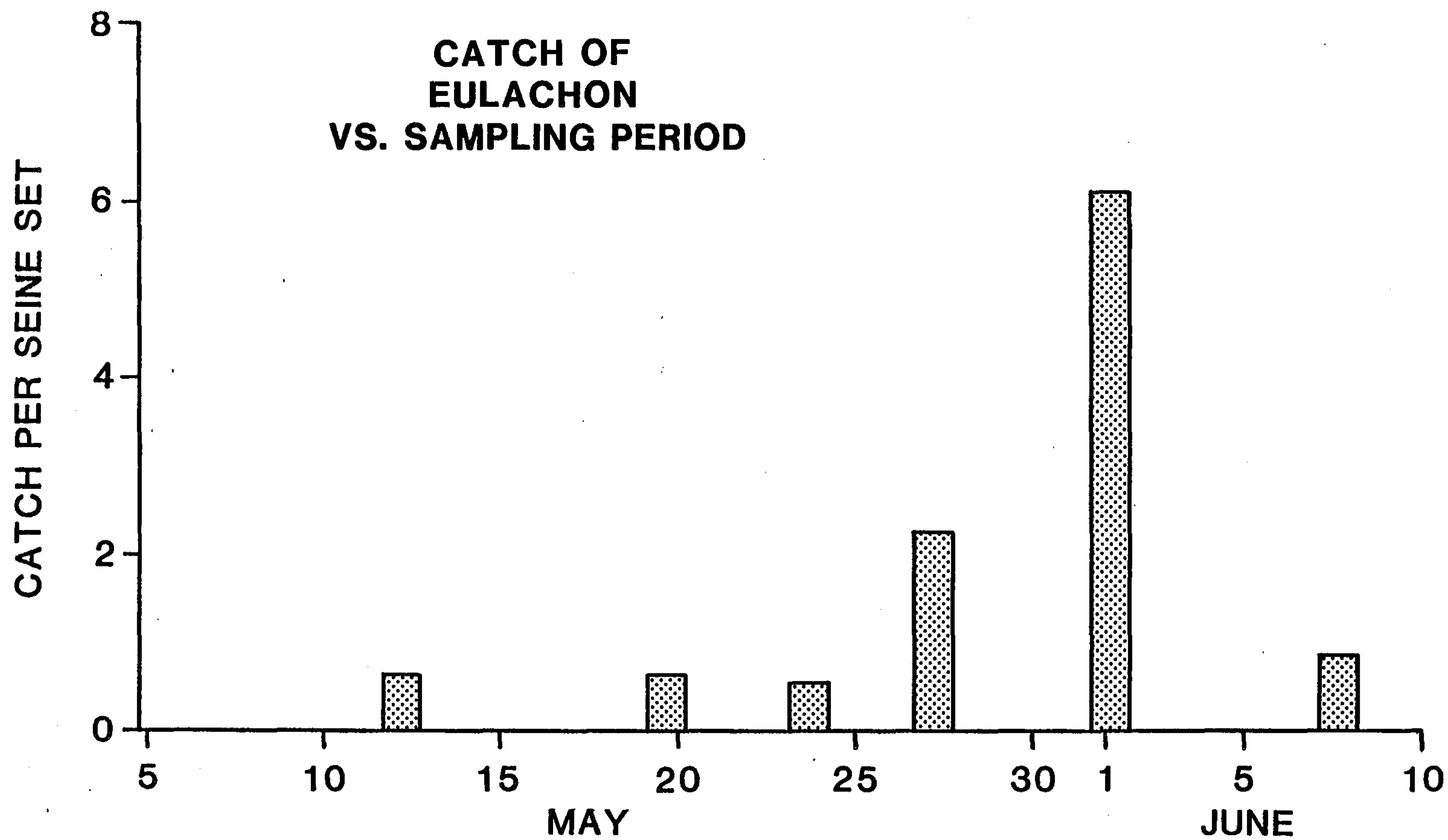
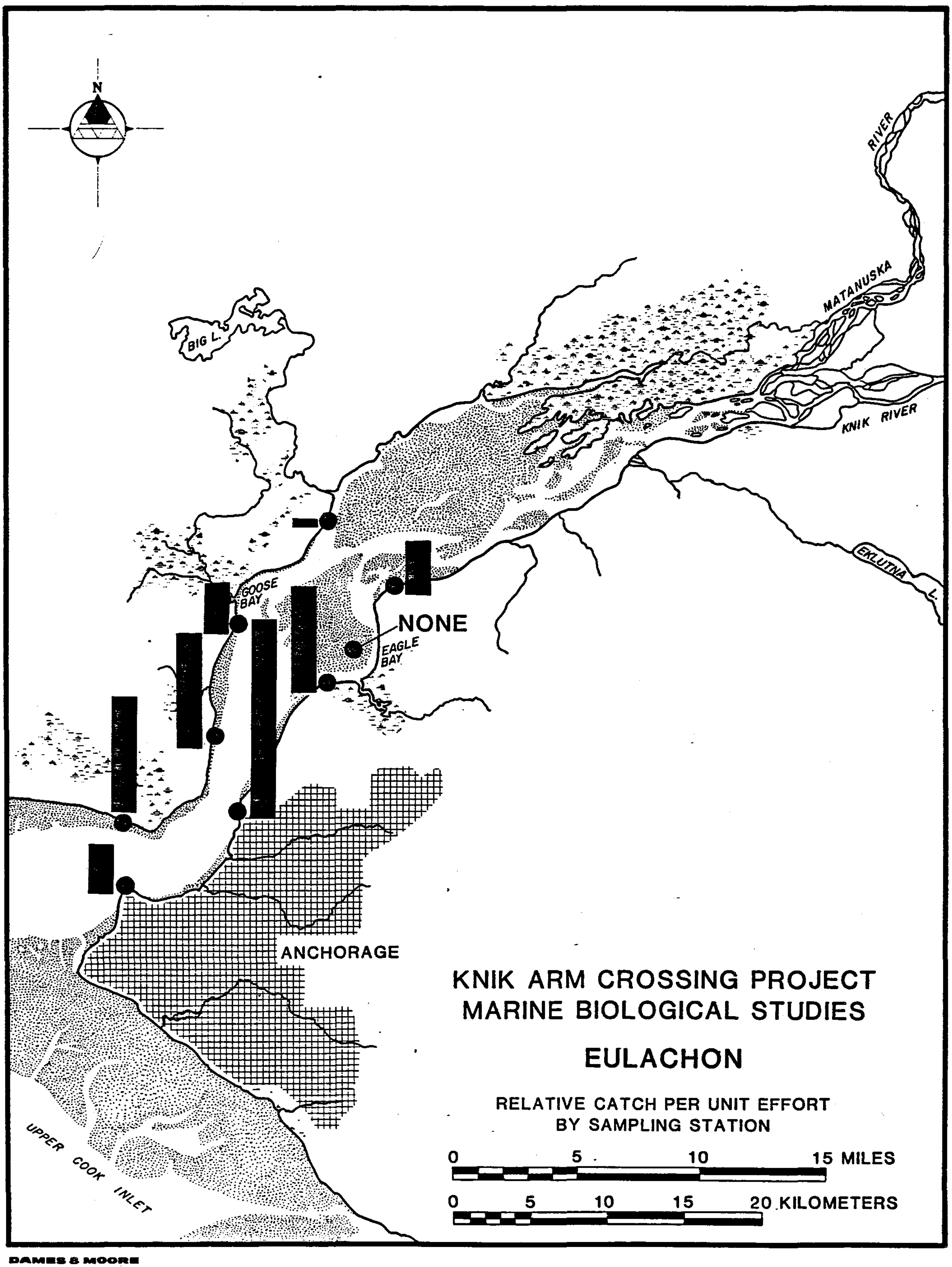

CATCH OF
EULACHON
VS. SAMPLING PERIOD
CATCH PER SEINE SET
0
2
4
6
8
5
10
15
20
25
30
1
5
10
MAY
JUNE

Figure 21


N
BIG L.
RIVER
MATANUSKA
KNIK RIVER
EKLUTNA L.
GOOSE BAY
NONE
EAGLE BAY
ANCHORAGE
UPPER COOK INLET
KNIK ARM CROSSING PROJECT
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EULACHON
RELATIVE CATCH PER UNIT EFFORT
BY SAMPLING STATION
0 5 10 15 MILES
0 5 10 15 20 KILOMETERS
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Figure 22

TABLE 2

Relationship of Tide Stage to the Seine Catch of Major Fish and Invertebrates Within Knik Arm, Upper Cook Inlet

Species	Mid Tide - Rising[1] (CPS)[2]	High Tide (CPS)	Mid Tide - Falling (CPS)	Low Tide (CPS)
Juvenile Salmon (all species combined)	5.1	2.9	2.3	2.2
Threespine Stickleback	61.5	86.6	21.9	24.0
Saffron Cod	5.9	1.1	1.2	0.9
Bering Cisco	1.7	0.6	0.7	0.7
Eulachon	2.3	1.5	2.0	1.0
Total Fish	76.4	92.8	29.1	29.6
Epifaunal Invertebrates	23.0	5.4	10.3	7.0

1 Tidal cycle was divided into 4 3-hour segments. High tide includes a period of time 1-1/2 hours before and 1-1/2 hours after maximum high tide as determined from tide tables for the Port of Anchorage. Low tide was similarly determined and mid-tide segments include the periods of time between the high and low segments.

2 CPS = catch per set of the 37 m (121 ft) beach seine.

for the catch of most species to be highest during rising or flood tide at middle tide stages. This phenomenon was most pronounced for saffron cod.

Trawl Catch Data - Fish

Seven successful trawl hauls in the Eagle Bay channel at 6 to 11 m (20 to 35 ft) depths caught relatively few fish. The total catch was as follows:

Threespine stickleback	4
Eulachon	1
Saffron cod	2
Snailfish	9

Trawling was complicated by strong currents and abundant detritus and it was difficult to confirm whether the trawl was effectively deployed on each haul.

Invertebrate Catch Data

The beach seine employed as the primary fish collection gear also captured numbers of larger (>10 mm [>.4 in]) epibenthic invertebrates. Efficiency of capture was undoubtedly reduced by the small size of some groups (mysids, amphipods) and by the close association of some groups (Crangon, amphipods) with the bottom. Nonetheless, invertebrate collections from the beach seine appear to provide a reliable indicator of the relative abundance of larger epibenthos.

All invertebrates captured were Crustacea; diversity was low with only seven species represented (Table 3). There was a greater number of species taken in more southerly sites with only one to two species present in catches from upper arm Stations 2, 3, 5, and 6. Collections were characterized by strong numerical (93 percent) and weight dominance by crangonid shrimp, Crangon franciscorum and C. alaskensis. Crangon was especially abundant on the silty sand flats of the Middle Shoal Station 5 (24.4 per set) and in

TABLE 3

Epifaunal Crustaceans Observed in Knik Arm,
Upper Cook Inlet

Decapoda

Crangonidae

Crangon franciscorum

Crangon alaskensis

Mysidacea

Mysis litoralis

Neomysis mercedis

Neomysis rayii

Amphipoda

Eogammarus confervicolus

Isopoda

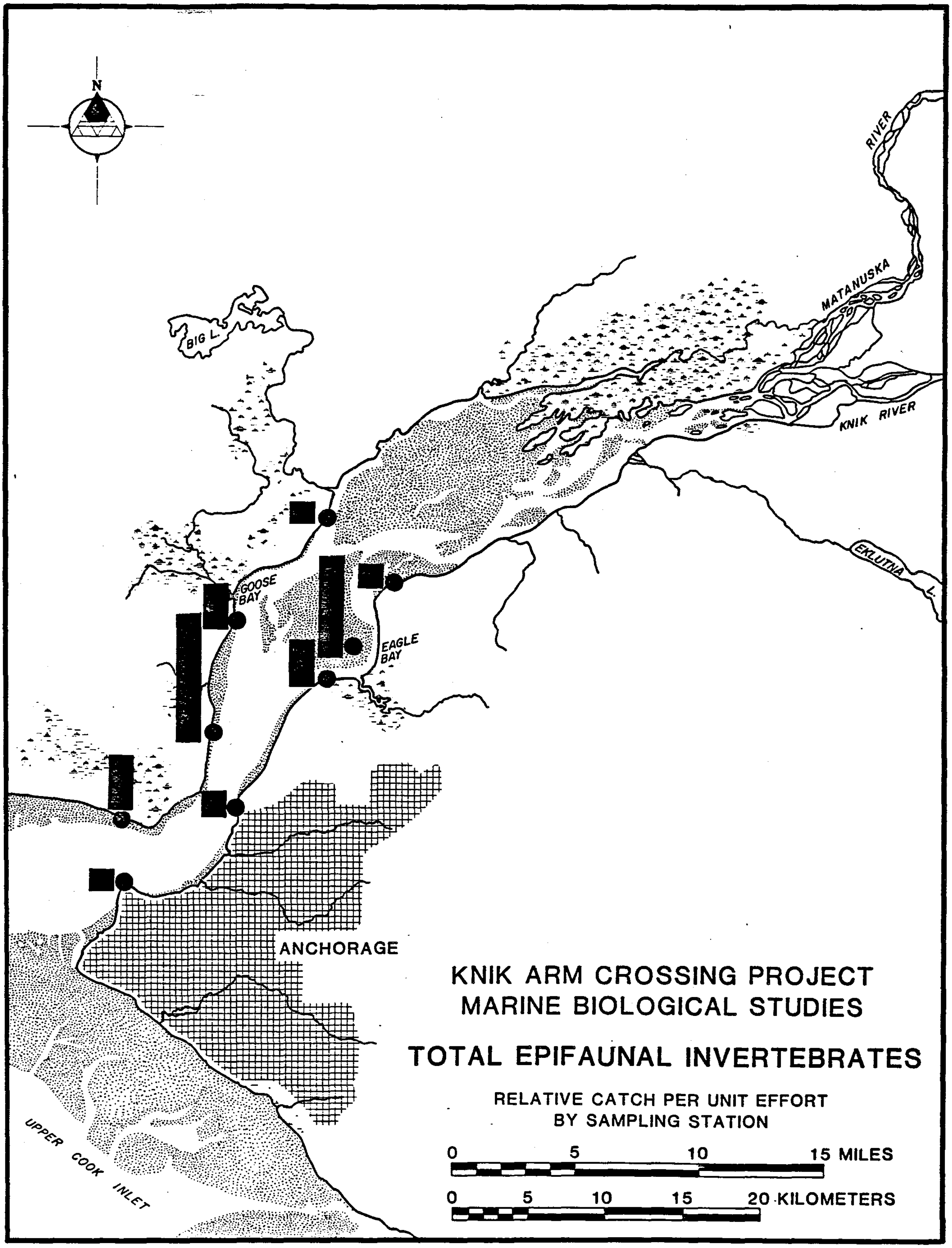
Saduria entomon

cobbly sand at Station 10 on the west side of the arm (31.3 per set, Figure 23). Average Crangon catch per set from May 11-27 was 4.9 (75 sets) increasing to 16.9 per set (39 sets) over the last two sampling periods (May 31 to June 8). The sharp increase in catch of Crangon in the last two sampling periods was largely responsible for the jump in total invertebrate catch in the same time frame.

The next most abundant invertebrate group was the Mysidacea represented by three species, Mysis litoralis, Neomysis rayii, and N. mercedis. The relatively large N. rayii was likely fairly efficiently sampled by the beach seine yet it was relatively rare (0.1 per set in 114 sets). The smaller mysids (N. mercedis and M. litoralis) were likely very poorly sampled by the beach seine based on their small size and their relative abundance in fish stomachs. Our catch (0.3 per set) was certainly not representative of the abundance and importance of these species. N. mercedis comprised some 90+ percent of the smaller mysids that were identified to species. Abundance of smaller mysids appeared to decline somewhat over the entire sampling period while the larger N. rayii showed an opposite trend. Total CPS of invertebrates was greatest (23.0 per set) on rising tides as compared to falling tides (10.3 per set), low tides (7.0 per set), and high tides (5.4 per set).

The gammarid amphipod Eogammarus confervicolous, like the smaller mysids, was probably not effectively taken by our seine (0.3 per set). This species showed an apparent increase in catch rate through the sample period and was only taken from Eagle River south. The large isopod Saduria entomon was captured but once on each sampling trip (0.04 per set overall). Again, this low catch rate may not be reflective of abundance of this species in the arm because of its close association with the bottom. This species was only taken in beach seines from Station 10 south.

The seven trawls that were made in the trough off Eagle River captured an average of 4.5 invertebrates each including all of the major taxa taken in the beach seines. Catch was again dominated by Crangon spp., although its dominance was less pronounced than in the beach seine (63 percent vs. 93 percent in the seines). For two taxa (E. confervicolous) and S. entomon) the trawl catch represented the farthest up-inlet capture in this study.



DAMES & MOORE

Figure 23

Core sampling at several beach areas about the arm failed to produce a single organism.

Attempts to use an epibenthic sled to sample small epibenthic Crustacea were foiled by the high suspended sediment load in the water which quickly and completely clogged the 0.209-mm mesh employed.

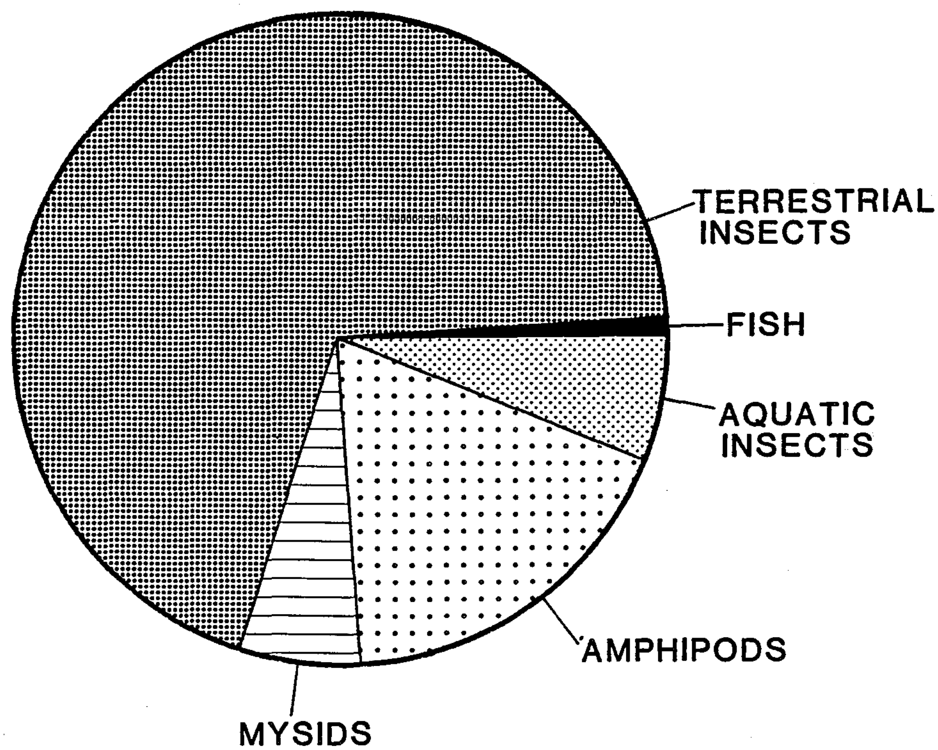
Marine Algae

Benthic algae were represented in the arm by two tolerant groups. A single attached specimen of the rockweed *Fucus distichus* was found at Station 3. The tubular green alga *Enteromorpha* sp. was initially seen about midway through the study (late May) and grew increasingly abundant on stable cobble and mud throughout the remainder of the study. Other vegetation is evident on upper mud flats later in the summer (e.g., around Earthquake Park and Pt. Woronzoff) but was not examined in this study.

Fish Food Habits

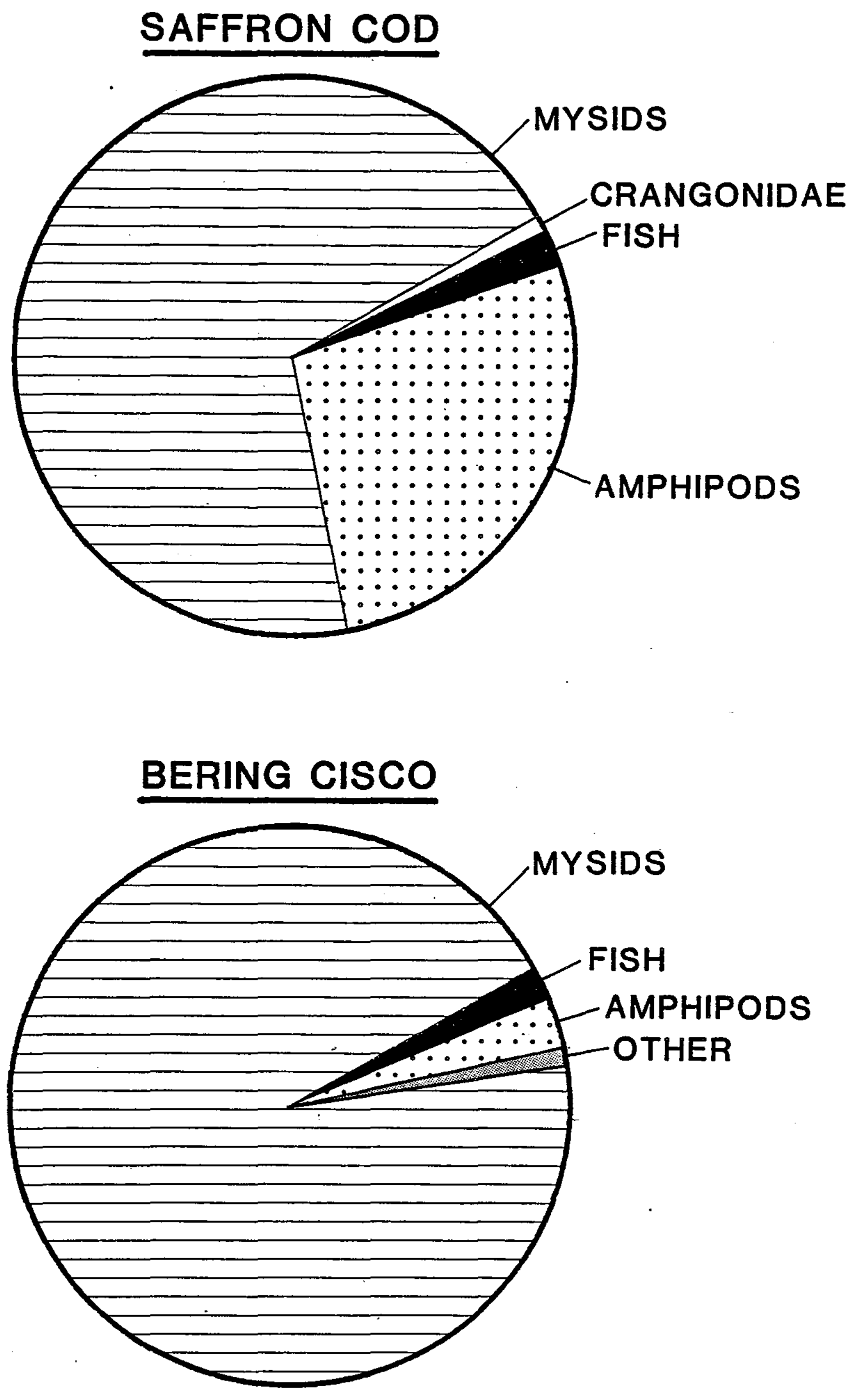
Juvenile Salmon. The results of the stomach content analysis for juvenile salmon are presented in Appendix C and summarized in Figure 24. The majority of food consumed by all species consisted of terrestrial insects (primarily winged adults). About 20 percent of the total number of separate food items consisted of Mysidacea or Amphipoda. About 25 percent of the stomachs containing food contained items of definite salt or brackish water origin. The terrestrial insects could have been obtained in either salt or fresh water while most of the aquatic insects observed in the stomachs were of definite freshwater origin.

Other Species. The dominant food item for species other than Pacific salmon was Mysidacea as exemplified by the diet of saffron cod and Bering cisco (Figure 25 and Appendix C). Amphipods were also an important item especially for the cod. Larger individuals of most species consumed significant numbers of fish. The vast majority of threespine stickleback and eulachon had empty stomachs.



DIET OF JUVENILE SALMON
WITHIN KNIK ARM,
UPPER COOK INLET
(BASED ON NUMBERS OF PREY)

Figure 24



DIET OF SELECTED FISH SPECIES
WITHIN KNIK ARM,
UPPER COOK INLET
(BASED ON NUMBERS OF PREY)

Figure 25

Bird Observations

Observations of birds made during the study period are summarized in Table 4. The primary areas of bird activity were in the vicinity of the Goose Bay Flats and Eagle River Flats. In addition to those listed in Table 4, scattered glaucous-winged and herring gulls were always present on the arm.

Marine Mammal Observations

No marine mammals were observed during the study.

D. DISCUSSION

Juvenile Salmon

Chum Salmon. Chum salmon fry appear to be present in Knik Arm in significant numbers from mid-May until at least mid-June and perhaps into July. A longer study period would have been needed to establish the total run duration. The rather long outmigration period is probably a result of contribution from several streams, with different temperature regimes and emergence times. Also, the length of freshwater residence varies among Alaska streams. For example, chum salmon hatched in the upper Susitna River spend up to six weeks in the river following emergence prior to outmigrating in mid-June (K. Roth, ADF&G, pers. comm.).

Two lines of evidence suggest that chum salmon fry have a short period of residence in Knik Arm. On the evening of May 30 the Cook Inlet Aquaculture Association released 1.1 million hatchery reared chum salmon fry into the lower Knik River (T. Mears, Cook Inlet Aquaculture Assoc., pers. comm.). The average size of these fish was substantially larger than the natural fish caught in Knik Arm in the beach seine. The east side of Knik Arm was sampled on May 31 and chum fry within the size range of hatchery fish (40-55 mm [1.6 to 2.2 in]) were caught as far south as sample Station 11. On June 7 the east side of Knik Arm was again sampled; all the chum salmon caught were smaller than the hatchery fish except for a few at Stations 12 and 13. These

TABLE 4

Summary of Bird Observations

Species	Date	Number Observed	Activity	Location
Mallard	5/10	4	Flying	Ship Creek
	5/13	3	Walking	Intertidal mud flat - Ship Creek
	5/24	2	Walking	Intertidal mud-flat - Earthquake Park area
Northern Pintail	5/12	5	Flying	Eagle River Flat
	5/12	1		Goose Bay
	5/13	2		Goose Bay
Green-winged Teal	5/24	2	Swimming	Nearshore - Earthquake Park
Greater Scaup	5/12	15	Swimming/Resting	Open water - mid-Arm
	5/12	48	Swimming/Resting	Nearshore - Goose Bay
	5/13	10	Swimming/Resting	Open water - South of Goose Bay
White-winged Scoter	5/13	4	Swimming/Resting	Open water - Pt. MacKenzie
	5/23	3	Swimming/Resting	Open water - Mid-Arm
	5/27	10	Swimming/Resting	Open water - Mid-Arm
Canada Goose	5/12	50	Walking	Goose Bay Flat
	5/12	200	Flying	Goose Bay Flat
	5/13	1	Walking	Intertidal mud flat - Ship Creek
	5/13	60	Walking	Goose Bay Flat
	5/23	2	Flying	Eagle River Flat
Red-necked grebe	5/10	3	Swimming	Open water - Mid-Arm
	5/12	4	Swimming	Near shore - Goose Bay
Arctic tern	5/10	2	Resting on floating logs	Near Eagle River
	5/12	2	Flying	Goose Bay Flat
	5/13	2	Flying	Goose Bay Flat
Gulls, Unid.	5/12	200	Resting	Goose Bay Flat
Small Shorebirds	5/13	5	Walking	Goose Bay Flat
Small Shorebirds	6/7	10	Flying	Eagle River Flat
Yellowlegs	6/7	1	Flying	Eagle River Flat
Bald Eagle	5/12	1	Flying	Eagle River Flat
	5/12	2	Roosting	On bank south of Goose Bay
	5/13	1	Roosting	In tree South of Eagle River
	5/27	1	Flying	South of Eagle River
	6/7	1	Roosting	In tree south of Eagle River

data suggest that the hatchery fry moved out of Knik Arm rapidly within a week or less. Additionally, only three chum fry contained food items that were definitely of saltwater origin, while most of the fry had either empty stomachs or contained winged insects that were most likely ingested in freshwater.

Coho Salmon. Coho juveniles were apparently present in Knik Arm from about May 20 until at least mid-June with a peak of abundance probably occurring in early June. This timing agrees with data collected by ADF&G at outmigrant weirs on Fish and Cottonwood Creeks, both of which empty into the west side of Knik Arm (Chlupach 1982 and B. Chlupach, ADF&G, pers. comm.). The strong catch at Station 2 (Figure 6) suggests that many of the coho smolts caught in the beach seine originated from Fish Creek.

The length/frequency analysis (Figure 7) suggests that three age groups of smolts may be present in Knik Arm. This again corresponds with the results of the weir studies (Chlupach 1982); age 1.0, 2.0 and 3.0 smolts are all present during the Fish and Cottonwood Creeks outmigration with age 2.0 fish dominating. The group of very small cohos (30-40 mm [1.2 to 1.6 in]) is more puzzling. These are almost certainly age 0 fish as some were not completely "buttoned up" (traces of the yolk sac were visible). The number of fish in this size group is small (6 fish) and they may have entered Knik Arm accidentally during a spring freshet. On the other hand, these small cohos may suggest that some rearing occurs in the estuary. Studies of other estuaries suggest that age 0 cohos are unusual in salt or brackish waters (Healy 1980; Bax et al. 1980).

A relatively short residence time in Knik Arm is implied by the dominance of terrestrial insects in the diet. However, this result may be biased by the fact that many cohos were caught near Fish Creek and may have just entered Knik Arm. On the other hand, 30 percent of the stomachs containing food contained items of saltwater origin suggesting that coho smolts feed to a greater extent in Knik Arm than chum fry. However, 60 percent of the stomachs contained no food.

Sockeye Salmon. The timing of juvenile sockeye salmon presence in Knik Arm appears to be similar to that of the coho salmon except that the peak of abundance may be somewhat later and the run may taper off more slowly. The ADF&G weir data for past years tend to agree with this chronology (Chlupach 1982). The midpoint of sockeye smolt outmigration in Fish Creek in 1983 was about June 8 (Chlupach, ADF&G, pers. comm.).

The length/frequency analysis (Figure 10), however, does not agree well with the lengths of fish caught in the Fish or Cottonwood Creek weirs. Chlupach found age 1.0, 2.0 and 3.0 sockeye smolts among the outmigrants in 1982 with mean sizes of about 120 mm (4.7 in), 165 mm (6.5 in)and 172 mm (6.8 in) respectively. The 1983 weir data had not been compiled at the time this report was written but sizes appeared to be at least as large as in 1982 (B. Chlupach, ADF&G, pers. comm.). Nearly all of the sockeye smolts caught in our seine were smaller than the age 1.0 mean, which may suggest that the beach seine does not adequately sample the larger sockeye smolts. The larger sockeye smolts may head for open water and thus not be vulnerable to capture along the shore. There was also a small group of probable age 0 fish (30-40 mm [1.2 to 1.6 in]). As with the coho, it is not known whether these small fish indicate saltwater rearing or whether the fish are an anomaly. Sockeye rearing does occur in brackish water in some areas (Healy 1980). It is also possible that mistakes in species identification were made since small sockeye salmon were difficult to distinguish from chum salmon fry.

Short residence time within Knik Arm is also suggested for sockeye smolts based on the high percentage of adult insects in the diet. However, about 30 percent of the sockeyes had consumed foods of saltwater origin suggesting that active feeding occurs while in transit.

Chinook Salmon. The beginning of the chinook salmon smolt outmigration appeared to occur at about the same time as for the other juvenile salmon. No prominent peak of abundance was noted during the study period. The study duration was too short to determine the end point of the outmigration period and it is possible that a peak may have occurred after the last sampling date. Little information exists to shed additional light on the timing of chinook outmigration in Knik Arm since very few chinooks are caught in the ADF&G weirs.

The sample size for chinook smolts was too small to allow an adequate analysis of size/frequency and age composition. However, a wide range of sizes was captured and several different age classes probably participated (Figure 13). As with coho salmon, a small group of probable age 0 fish was among the catch. Information from Washington and British Columbia suggests that estuarine rearing of chinooks is not uncommon (Healy 1980, Bax et al. 1980).

Although the sample size is small, more than half of the chinooks that had food in their stomachs contained items of saltwater origin. This suggests that chinooks are able to more efficiently exploit the resources of Knik Arm than the other salmon outmigrants, or perhaps spend more time there.

Pink Salmon. The low catch of pink salmon probably reflects the minimal spawning that occurs in Knik Arm streams during even years. Beach seining is normally an efficient method of sampling pink salmon because they are oriented to the shoreline during the first few weeks in saltwater (Healy 1982); therefore, the low catch is probably a real indication of low abundance. Significant outmigration could have occurred outside of the study period, but this possibility seems unlikely in view of the timing of the other salmon.

Species Other Than Pacific Salmon

Eulachon and threespine stickleback are both anadromous species and it seems likely that most of the members of these species caught in the seine were in the process of migrating to or from Knik Arm streams for spawning. This conclusion is supported by the sharp peak of abundance, preponderance of adult fish, some of which were in spawning or spawned out condition, and high proportion of empty stomachs. It is suspected that threespine sticklebacks are residents as well as migrants within Knik Arm. The catches of stickleback late in the study period may be representative of the resident population. It is not known whether eulachon reside in Knik Arm at times of the year other than during the spawning migration.

Saffron cod and Bering cisco were relatively abundant and appear to be well adapted to survival in the rigorous Knik Arm environment during at least part of the year. The presence of these resident fish in substantial numbers was one of the more surprising aspects of the study. Bering cisco have been reported previously in Upper Cook Inlet (Blackburn 1978); but little is known of the life history of anadromous populations. It seems likely that humpback whitefish reported near Pt. Woronzoff (U.S. Army Corps of Engineers 1979), were misidentified and were actually Bering cisco. The cisco presumably spawn in the fall in area streams and may reside in the estuary for the remainder of the year. Saffron cod were also reported by Blackburn (1978) in beach seine hauls in Cook Inlet as far north as the East Forelands. U.S. Army Corps of Engineers (1979) reported Pacific tomcod as present near Point Woronzoff; these fish may have actually been saffron cod. Saffron cod inhabit coastal areas and are known to be tolerant of low salinity (Blackburn 1978 and Morrow 1980). Adult cod move into deep water in the summer which probably explains the dominance of juveniles in our samples. The adults return to shallow areas influenced by tidal currents in the winter to spawn (Andriyashev 1954 cited in Blackburn 1978). The number of juvenile saffron cod in Knik Arm suggests either that adults spawn there or that juveniles move into the arm from a nearby area.

The cod and cisco as well as other species such as snailfish and longfin smelt are able to feed effectively in the turbid Knik Arm environment. The catch vs. tide stage analysis (Table 2) suggests that cod and cisco may inhabit beach areas during the rising tide, following the water line as it advances shoreward. It is possible that this behavioral mechanism is related to feeding since the invertebrates seem to have a similar movement pattern. Water clarity would be expected to be somewhat greater during the flood tide and may enhance feeding. However, turbidity even at best is very high and the mechanism by which these fish locate their food is unknown.

All of the other species of fish caught during the study have been reported previously in Cook Inlet (Blackburn 1978). The presence of Pacific herring juveniles and ripe adults in outer Knik Arm may be of some interest. Blackburn caught juvenile herring as far north as the East Forelands and suggested that his data supported the hypothesis of a herring spawning area in Upper Cook Inlet north of the Forelands. Our data tend to confirm that idea.

A surprising aspect of our catch data is the lack of Dolly Varden. Dolly Varden were one of the more abundant species caught by Blackburn in his beach seine in lower Cook Inlet.

Overall Fish Productivity

Overall productivity of Knik Arm is difficult to compare to other Alaskan coastal areas. Beach seining is a semi-quantitative method and many of the fish caught during the study were transients. Nevertheless, some insight into relative productivity can be gained by looking at the results of other studies using similar sampling techniques.

The overall catch per set of juvenile salmonids in Knik Arm beach seining (2.5 per set) can be compared to catches recorded by Dames & Moore elsewhere in the state using the same net and technique. In two lagoons in the south east Chukchi Sea an average of 1.86 juvenile anadromous salmonids (pink salmon and Arctic char) was taken in 14 sets during the 1983 spring out-migration (Blaylock and Houghton 1983). Seining in the Gastineau Channel near Juneau in late March of 1982 produced chum and pink smolts at a rate of 1.3 per set. However, this sampling likely preceeded the seasonal peak of juvenile salmon in the area (Dames & Moore 1982a).

In a more productive area in Washington's Puget Sound, catches of 25-40 juvenile salmonids per set (chinook, coho, pinks and chums) were common during the 2 month period of outmigration with much higher numbers (to 200 per set) in sampling that followed major hatchery releases (Dames & Moore 1982b).

Blackburn (1978) sampled various areas in lower Cook Inlet with a 47 m. (155 ft) beach seine. Although his net was longer than that used in this study, his techniques were similar and catches should be roughly comparable. The results for three areas sampled by Blackburn in June are presented below:

Area	Juvenile Salmon (CPS)	Total Fish (CPS)
East side of Lower Cook Inlet (Anchor Pt. to the Forelands)	2.9	45
West side of Lower Cook Inlet	1.2	13
Kachemak Bay	26.0	552

Catches on the east side of Lower Cook Inlet were very similar to those of this study which is not unexpected since the environment is similar to Knik Arm. Catches were substantially lower on the west side of Lower Cook Inlet. Kachemak Bay is known to be a highly productive environment and, as anticipated, the CPS was much higher than in Knik Arm. It should be noted, however, that the catch statistics for Kachemak Bay include one very large haul of sand lance which accounted for about 400 of the total 552.

Blaylock and Erikson (1983) used a 61 m (200 ft) seine to sample fish on Chukchi Sea beaches in June and July. An average of 19 fish per set were caught in 56 seine hauls at 15 stations.

The results of these various studies suggest that the fish productivity of Knik Arm nearshore areas is moderate when compared to nearshore environments in other areas of Alaska.

Birds

Bird use of the open water or near shore habitats is minimal. The few white-winged scoters and scaup that were observed were probably resting; no feeding behavior was observed. The poor visibility and lack of benthic organisms undoubtedly discourage use by diving birds. Shorebird use of the typical eroding bluff/narrow beach shoreline is assumed to be minimal because no shorebirds were observed in these habitats which is probably a reflection of the low levels of intertidal fauna.

The primary areas of bird activity were the mud flat/marsh habitats associated with the Goose Bay State Game Refuge and the Eagle River delta. Additional activity by dabbling ducks was noted on broad intertidal mud flats adjacent to the Anchorage metropolitan area; algal growth on the upper intertidal substrate may be the major attraction for these species.

The consistent sitings of bald eagles on the bluff south of the Eagle River mouth suggest a nest in this vicinity.

Trophic Relationships

The limited amount of previous biological sampling in Upper Cook Inlet, including Knik and Turnagain Arms, has done little to elucidate the ecological importance or trophic structure of the area. While the present study did little more than hint at the answers to these questions, it has at least provided strong evidence that the questions are worth asking. Knik Arm does have an ecological value that surpasses its role as a transportation corridor for anadromous fish. The following discussion is based on very limited sampling and observations of Knik Arm and can well be expected to undergo major revisions as more data become available.

Clearly Knik Arm is an extremely rigorous environment with little opportunity for benthic algae, infauna, or sessile epifauna to develop in the manner common in Lower Cook Inlet (Lees et al. 1980).

The primary source of organic carbon for the arm would appear to be the large quantities of fibrous and woody detritus entering from the many rivers, streams, and marshes tributary to the arm. On many occasions our seine and trawl became nearly completely clogged with this material. Primary production within the arm is clearly limited by the opacity of the water.

Phytoplankton productivity is certainly minimal and benthic macro and micro algae are probably limited to intertidal species that can photosynthesize effectively during periods of emergence. However, the broad intertidal areas present in the arm would maximize the importance of even a very low rate of carbon fixation per unit area. Nonetheless, direct herbivory is probably of limited importance in this environment even though the dominant species present (Crangon franciscorum and Neomysis mercedis) are known to feed significantly on diatoms at some times of the year in the substantially less turbid Columbia River Estuary (Simenstad and Cordell 1983). The remainder of the diet of these two species in the Columbia estuary was dominated by rotifers, cladocerans, and harpacticoid copepods. No sampling efforts on these smaller plankters have been conducted in Knik Arm, yet the presumed lack of primary production by micro algae would make their presence seem somewhat doubtful. Moreover, none were seen in stomachs of smaller fish examined. If there is, in fact, little micro algae and few smaller zooplankton in Knik Arm, then a major unanswered question is--upon what are the larger, usually predaceous zooplankton feeding? Some components of the detritus is a possibility that remains to be explored. Examination of archived samples would shed light on this.

The other two major invertebrates taken in these surveys are more readily assigned to the role of detritivores and scavengers. Robilliard and Busdosh (1979) report strong evidence that smaller Saduria ingest and apparently assimilate plant debris including peat in the Beaufort Sea. Eogammarus confervicolous is a dominant amphipod under cobbles on exposed beaches in lower Cook Inlet where it was usually feeding on plant or animal debris (Lees et al. 1980).

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APPENDIX A

BEACH SEINE CATCH BY SPECIES FOR EACH FIXED SAMPLING SITE - ALL SAMPLING PERIODS COMBINED

	STAT 2			STAT 3			STAT 5			STAT 6			STAT 7			STAT 10			STAT 11			STAT 12			STAT 13		
	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set
Chum Salmon	3	8	0.4	5	13	0.4	3	8	0.4	23	8	0.4	23	17	1.3	6	10	0.6	11	6	1.8	13	10	1.3	28	16	1.7
Sockeye Salmon	3	8	0.4	2	13	0.1	1	8	0.1	19	8	0.5	19	17	1.1	7	10	0.7	2	6	0.3	8	10	0.8	6	16	0.4
Coho Salmon	21	8	2.6	1	13	0.08	1	8	0.1	--	8	0.7	--	17	--	13	10	1.3	10	6	1.7	13	10	1.3	13	16	0.8
Chinook Salmon	--	8	--	1	13	0.08	1	8	0.1	4	8	0.4	4	17	0.2	10	10	1.0	4	6	0.7	8	10	0.8	7	16	0.4
Pink Salmon	--	8	--	--	13	--	--	8	--	--	8	--	--	17	--	1	10	0.1	--	6	--	--	10	--	9	16	0.6
Dolly Varden	--	8	--	--	13	--	--	8	--	--	8	--	--	17	--	3	10	0.3	--	6	--	--	10	--	--	16	--
Rainbow Trout	1	8	0.1	--	13	--	--	8	--	--	8	--	--	17	--	--	10	--	--	6	--	--	10	--	--	16	--
Bering Cisco	--	8	--	--	13	--	--	8	--	26	8	0.9	26	17	1.5	19	10	1.9	6	6	1.0	9	10	0.9	16	16	1.0
Eulachon	1	8	0.1	19	13	1.5	--	8	--	43	8	1.0	43	17	2.5	27	10	2.7	30	6	5.0	27	10	2.7	17	16	1.1
Longfin Smelt	--	8	--	--	13	--	--	8	--	--	8	--	--	17	--	1	10	0.1	--	6	--	2	10	0.2	--	16	--
Saffron Cod	4	8	0.5	2	13	0.1	4	8	0.5	24	8	1.4	24	17	1.4	44	10	4.4	11	6	1.8	38	10	3.8	35	16	2.1
Pacific Herring	--	8	--	--	13	--	--	8	--	--	8	--	--	17	--	1	10	0.1	--	6	--	1	10	0.1	3	16	0.2
Snailfish	--	8	--	2	13	0.1	--	8	--	2	8	--	2	17	0.1	--	10	--	--	6	--	1	10	0.1	7	16	0.4
Starry Flounder	--	8	--	--	13	--	--	8	--	2	8	--	2	17	0.1	--	10	--	--	6	--	--	10	--	--	16	--
Yellowfin Sole	--	8	--	--	13	--	--	8	--	--	8	--	--	17	--	--	10	--	--	6	--	1	10	0.1	--	16	--
Threespine Stickleback	254	8	32	285	13	22	258	8	32	942	8	118	1053	17	62	163	10	16	--	6	--	1492	10	1490	68	16	4
Ninespine Stickleback	--	8	--	--	13	--	--	8	--	2	8	0.4	2	17	0.1	--	10	--	2	6	0.3	1	10	0.1	2	16	0.1
Pacific Staghorn Sculpin	--	8	--	1	13	0.08	--	8	--	--	8	--	--	17	--	--	10	--	--	6	--	--	10	--	--	16	--

APPENDIX B

BEACH SEINE CATCH BY SPECIES FOR EACH SAMPLING PERIOD

	May 11-13			May 19-20			May 23-24			May 27			May 31-June 2			June 7-8			Total/All Periods		
	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set	Total Catch	No. of Sets	Catch Per Set
Chum Salmon	2	12	0.1	10	22	0.5	15	27	0.6	9	14	0.6	33	20	1.6	34	19	1.8	103	114	0.9
Sockeye Salmon	--	12	--	5	22	0.23	12	27	0.4	5	14	0.4	18	20	0.9	13	19	0.6	53	114	0.5
Coho Salmon	--	12	--	2	22	0.1	14	27	0.6	2	14	0.1	45	20	2.2	15	19	0.7	78	114	0.7
Chinook Salmon	--	12	--	7	22	0.3	7	27	0.3	3	14	0.2	10	20	0.5	11	19	0.6	38	114	0.3
Pink Salmon	--	12	--	1	22	0.05	7	27	0.3	1	14	0.07	--	20	--	1	19	0.05	10	114	0.059
Dolly Varden	--	12	--	--	22	--	--	27	--	--	14	--	3	20	0.1	--	19	--	3	114	0.03
Rainbow Trout	1	12	--	--	22	--	1	27	0.04	--	14	--	--	20	--	--	19	--	1	114	0.1
Bering Cisco	13	12	1.1	6	22	0.3	21	27	0.8	17	14	1.2	13	20	0.6	13	19	0.7	83	114	0.7
Eulachon	8	12	0.7	15	22	0.7	16	27	0.6	32	14	2.3	137	20	6.8	16	19	0.8	224	114	2.0
Longfin Smelt	--	12	--	--	22	--	--	27	--	--	14	--	1	20	0.05	2	19	0.1	3	114	0.03
Saffron Cod	1	12	0.08	23	22	1.0	51	27	1.9	16	14	1.1	28	20	1.4	62	19	3.3	181	114	1.6
Pacific Herring	--	12	--	1	22	0.04	--	27	--	--	14	--	--	20	--	4	19	0.2	5	114	0.04
Snailfish	2	12	0.2	6	22	0.3	6	27	0.2	1	14	0.07	6	20	0.3	--	19	--	21	114	0.2
Starry Flounder	--	12	--	2	22	0.1	--	27	--	--	14	--	--	20	--	--	19	--	2	114	0.02
Yellowfin Sole	--	12	--	--	22	--	2	27	0.07	--	14	--	--	20	--	--	19	--	2	114	0.02
Threespine Stickleback	2828	12	236	773	22	35	427	27	16	124	14	8.9	228	20	14	191	19	10	4631	114	40.6
Ninespine Stickleback	3	12	0.2	1	22	0.04	1	27	0.04	1	14	0.07	4	20	0.2	1	19	0.05	11	114	0.1
Pacific Staghorn Sculpin	--	12	--	--	22	--	--	27	--	--	14	--	--	20	--	2	19	0.01	2	114	0.02

APPENDIX C

RESULTS OF STOMACH CONTENT ANALYSIS FOR KNIK ARM FISH

	Chum Salmon		Sockeye Salmon		Coho Salmon		Chinook Salmon		Pink Salmon	
No. Exam	76		47		67		33		7	
No. W/Food	50		31		26		17		1	
No. Empty	26		16		41		16		6	
Food Item	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]
Terrestrial Insects	80	5	83	9	46	2	52	2	100	2
Aquatic Insects	6	0.2	19	0.2	30	0.6	11	0.2		
Mysidacea	4	0.1	19	0.9			6	0.2		
Amphipoda	2	0.1	12	0.8	38	1.2	35	2.1		
Isopoda										
Crangonidae										
Polychaeta										
Fish (Total)					8	0.08				
Salmonidae					4	0.04				
Threespine Stickleback										
Ninespine Stickleback										
Enlachon										
Longfin Smelt							6	0.1		
Unidentified					4	0.04				
Fish Eggs										

[1] Percent Frequency = percentage of stomachs with food in them that contained the subject food item.

[2] Number per Stomach = the mean number of subject food items per stomach - all stomachs containing food were included in the calculation.

APPENDIX C

RESULTS OF STOMACH CONTENT ANALYSIS FOR KNIK ARM FISH

	Bering Cisco		Enlachon		Longfin Smelt		Saffron Cod		Pacific Herring	
No. Exam	22		32				55		3	
No. W/Food	15		5				47		2	
No. Empty	7		27				8		1	
Food Item	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]
Terrestrial Insects	6	0.06								
Aquatic Insects	6	0.06								
Mysidacea	46	33	60	36			72	10	100	40
Amphipoda	26	1.1	40	1.2			65	4		
Isopoda										
Crangonidae							13	0.1		
Polychaeta	6	0.3								
Fish (Total)	13	0.5	20	0.2			10	0.2		
Salmonidae	6	0.06								
Threespine Stickleback			20	0.2			2	0.02		
Ninespine Stickleback							2	0.04		
Enlachon							2	0.04		
Longfin Smelt										
Unidentified	6	0.5					4	0.08		
Fish Eggs			20							

[1] Percent Frequency = percentage of stomachs with food in them that contained the subject food item.

[2] Number per Stomach = the mean number of subject food items per stomach - all stomachs containing food were included in the calculation.

APPENDIX C

RESULTS OF STOMACH CONTENT ANALYSIS FOR KNIK ARM FISH

	Snailfish		Threespine Stickleback		Ninespine Stickleback		Pacific Staghorn Sculpin	
No. Exam	5		21		4		2	
No. W/Food	4		3		1		1	
No. Empty	1		18		3		1	
Food Item	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach[2]	Percent Frequency[1]	No. Per Stomach
Terrestrial Insects								
Aquatic Insects								
Mysidacea	25	.25	33	3				
Amphipoda	75	1.25	67	2				
Isopoda					100	1		
Crangonidae								
Polychaeta								
Fish (Total)								
Salmonidae								
Threespine Stickleback							100	1
Ninespine Stickleback								
Enlachon								
Longfin Smelt								
Unidentified								
Fish Eggs								

1 Percent Frequency = percentage of stomachs with food in them that contained the subject food item.

2 Number per Stomach = the mean number of subject food items per stomach - all stomachs containing food were included in the calculation.

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